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OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW.

EIGHTY-FIRST SESSION, 1883-84.

I.—*Address to the Chemical Section.* By Robert R. Tatlock, F.R.S.E., F.I.C., F.C.S., President of the Section.

[Read before the Section, 12th November, 1883.]

When last I had the honour of addressing you, I took occasion to refer to some matters of considerable technical interest, which were then beginning to awaken much attention, no less on account of their gigantic importance, than by reason of their being the outcome, not of any fresh discovery, but merely of the bold and determined application of old and well-known principles of operating to facts and conditions equally old and familiar. Since that time—short as it is—much has been done, if not in the direction of actually developing the new industries which were, even then, more than foreshadowed, at least of indicating the character they are practically certain to take, and it is to the present aspect of some of these, among other matters, that I would seek briefly to direct your attention to-night.

There is, perhaps, no better illustration than that of the recovery of ammonia and other volatile products from waste gases, of the hitherto too little recognised fact that it is not alone novelty or discovery that is wanted to institute or promote a new industry, but rather a clear perception of where and how existing knowledge and experience can be brought to bear upon subjects which may

have been long-waiting not for investigation really, but only for resolute action.

For many years the existence of ammonia in blast-furnace gases was well known, but several circumstances rendered it apparently unlikely that it could be recovered economically. The extremely small proportion of ammonia—amounting to only about ·08 per cent.—coupled with the high temperature and enormous volume of the gases to be handled, rendered it seemingly a very hopeless task to extract profitably so minute a quantity, especially as it was taken for granted that the furnace gases must necessarily be cooled down to average atmospheric temperature, or even below that, in order to obtain it. Still it seems incredible that for so long a time a sum of not less than £200,000 per annum of clear profit was thrown away in Scotland alone, not through ignorance, not from requiring to wait on some original discovery, but merely for want of a simple trial of whether the ordinary methods of recovering ammonia were capable of application to these gases. Naturally the principle of cooling the gases, which is followed at gas-works, was first tried, and at once proved equal to the task of removing the greater part, if not the whole, of the valuable ingredient; but it was soon found that this cooling could be dispensed with, and that mere scrubbing of the hot gases with acids fixed the ammonia perfectly, and at an initial cost for plant of a mere fraction of the cooling method. For a time it was supposed that the so-called "tar," which was condensed in the latter process, would not be obtained, or at least only partially, by the hot-scrubbing method, and that even in the latter case, what was condensed would be heavy and deficient in valuable light oils, such as are employed in the manufacture of aniline, as compared with the other. This doubt arose from a want of knowledge, first, of the mechanical condition in which the so-called tar existed in the waste gases, and, secondly, from its true nature and composition not being at the time recognised. No doubt, if the tar had been rich in benzole and toluol, cooling would have been necessary in order to secure these, but it would be required only to condense the vapours of these light oils or spirits which were *invisible* in the gases, the *visible* smoke or vapour existing in the hot gases, and which constitutes the greater part of the so-called "tar," requiring only *surface contact* in order to fix it in the fluid condition.

Whatever may have been supposed at one time, it is but too clear now that the crude tarry oils which are condensable from

blast-furnace gases are not going to be worth the cost of refrigerating apparatus; and it is now demonstrated beyond dispute, by practice, on an extensive working scale, that the latter is not necessary for the recovery of the ammonia, nor even is it required in order to recover the tar, the greater proportion of which can be obtained without purposely cooling at all. Even if these crude oils or tars had anything of the nature and value of coal tars, they must ever remain of secondary importance, from the comparatively small proportion yielded by a given weight of coal—say 10 gallons for every ton of coal used in the furnace. They must, therefore, always be regarded as a bye-product of comparatively small value, the ammonia being the product in chief. This will be admitted if we consider the relative value of the two products, taking the former at say 1d. per gallon, and the latter at the present average price of $1\frac{3}{4}$d. per lb., and a yield of 30 lbs. sulphate per ton of coal. The comparative market values calculated on the ton of coal are thus—10d. against 4/$4\frac{1}{2}$; but, deducting all costs from the latter, which do not exceed 1/$10\frac{1}{2}$, there remains a clear profit of 2/6 for ammonia, as compared with 10d. for the tarry oils, even on the basis of taxing the former with all the costs, and the latter with none whatever. In gas-works the conditions are altogether different, as there is not only a valuable tar to secure—rich in benzole and toluol, and, it may be, in anthracene also—which can only be accomplished by a process of condensation by cold, but there is only about $\frac{1}{13}$th part of the volume of gas to handle for a given quantity of volatile products recovered, and a given weight of coal used, or say 10,000 against 130,000 cubic feet per ton of coal; and not only so, but the coal gas as well as the tar has an immensely higher value on account of its greater illuminating and heat-giving power when burned, as compared with blast-furnace gases, and consequently will admit of a much more expensive treatment.

A glance at the nature of the distillation of coal which occurs respectively in gas retorts and in blast furnaces will show us that the products in each case must be different, the conditions, particularly as regards temperature, being quite different. In the former we have the immediate application of a high temperature penetrating, with rapidity, the comparatively small thickness of coal. In the latter the coal is mixed with more than its own weight of cold and inert ironstone and limestone, which aid in preventing the subjection of the coal suddenly to a

high temperature; so that the evolution of volatile products takes place at a comparatively low heat, producing principally paraffins, and little or no benzole and toluol, such as we have at the one end of true coal tar series; and little or no naphthaline and anthracene, such as we have at the other end. From theoretical considerations, therefore, we should not expect the same products, and in practice we do not find them the same. About two years ago I had occasion to examine a sample of blast-furnace "tar," obtained by cooling in the ordinary way, as to the nature and value of its constituents as compared with gas tar. This sample had a sp. gr. of 1·005, and lost 33 per cent. by simple distillation to coke. It contained no benzine; but about 9 lbs. of paraffin per 100 gallons. I reported that it was not of the nature of coal tar at all, but an extremely crude paraffin oil, requiring such a large proportion of sulphuric acid and caustic soda to refine it, and so small a proportion of products as compared with ordinary crude shale oil, that it would not pay to treat it as such. My experience has been completely borne out by an investigation recently made by Mr. Watson Smith, and recorded in a paper read by him at the last meeting of the British Association. This memoir is of a most interesting character, and points clearly to the future of these so-called tars, whether obtained from blast-furnaces or from coking ovens. In a recent report of this paper we are informed that he has investigated the tars from various coking ovens, including the Jamieson's, and the most improved form of Simon-Carves. He finds that the tar from the former has a sp. gr. of only ·960, and that in it no benzole—the representative member of the benzole series—exists, although small quantities of toluol, and larger quantities of xylol, are found; while both naphthaline and anthracene are entirely absent. On the other hand, he has observed that the tar from the most improved form of the Simon-Carves coking ovens has a high density (1·200), and that it is exceedingly rich in anthracene and naphthaline; while for yield of benzine, toluene, xylene, and carbolic acid, it is equal to the best tars produced at any of the London gas-works. This author points out that the difference in the chemical character and constituents of the two tars arises from the difference in treatment, particularly as regards temperature, which the coals receive during distillation in the respective coke-ovens; the more valuable ingredients in the Simon-Carves tar being the result of rapid distillation in a close oven, at a high temperature, without any

combustion. He predicts, therefore, that as the latter, in every particular, yields true coal-tar products, and first-class ammonia, liquor and coke, it will be the oven of the future. In passing, it may be worthy of notice that a more flagrant example of prejudice and of drawing foregone conclusions could scarcely be quoted than that of the resistance which has hitherto been offered on the part of the representatives of the coke-making industry, to the recovery of valuable volatile products, on the ground that this would necessarily interfere with the quality of the coke produced—a fear which has, quite recently, been proved to be altogether groundless—the Simon-Carves coke, even for iron-smelting purposes, at least rivalling all its predecessors.

If these indications be correct, let us glance for a moment at the probable results of the adoption of this oven, even to the extent of *half* the amount of coal coked in this country, which may be taken at the low estimate of 20,000,000 tons per annum. We shall begin with the ammonia. There is no doubt that, with the old forms of coking oven, hitherto employed, as much nitrogen was evolved in the distillation as in the blast-furnace or the Siemens' or Wilson's gas producer, but comparatively little, if any, appeared in the form of ammonia, the reason being that, from the introduction more or less of air, a partial combustion of the gases, and even to some extent of the fixed carbon also, took place, and this would be accompanied or followed by the decomposition or destruction of the ammonia, facilitated by the fact that nitrate of ammonia—one of the products of the combustion of ammonia in air—is so easily decomposed by heat into laughing gas and water. It is but reasonable to infer from this that the use of an essentially close oven such as the latest Simon-Carves would give an increased yield of ammonia as well as of good tar, and this conclusion is fully borne out in practice. I am informed on the authority of those who are most competent to judge that the yield of sulphate of ammonia per ton of coal is in practice from 20 to 30 lbs., while that of tar is about 7 gallons. These figures applied to an annual output of coke obtained from 10,000,000 tons of coal will give, at the rate of 25 lbs. sulphate of ammonia per ton of coal, 250,000,000 lbs. To this must be added about 45,000,000 lbs. which is certain to be produced from blast furnaces in Scotland alone, and as much more from blast furnaces working entirely and partly on coal in England, and from gas generators in the United Kingdom, taken together. There stands thus a total of 340,000,000 lbs.—151,785

tons—for this country, the present output being about 70,000 tons. The accompanying tar will measure 70,000,000 gallons. At first sight it would appear that this enormous amount of ammonia cannot be wanted, and that the fall in price naturally consequent upon such a vastly and suddenly increased output would check the production or sink the price to an unremunerative figure. It must be borne in mind, however, that it is only the supply which is produced in excess of the natural demand which results in these undesirable consequences; and I think I shall be able to show that there is little danger of sulphate of ammonia falling below what will be a remunerative rate to manufacturers, especially such as have not prospectively long contracts for gas liquor at the present high rate. The question presents itself—is there room for so great an increase in that article? Undoubtedly there is, if it can be made at a price which will induce present consumers of nitrate of soda for manurial purposes to adopt it in preference to the latter article. Let us see whether this is probable! In the year which fell between 1st July, 1882, and 30th June, 1883, there were consumed in the entire world 430,000 tons of nitrate of soda. If we deduct from this 100,000 tons used for the manufacture of nitric acid, &c., we have a balance of 330,000 tons which were undoubtedly employed for manurial purposes, the average price during that time being £12 5s. per ton. Now, in view of competition with sulphate of ammonia, it is of primary importance to know the lowest price at which nitrate of soda can be delivered, say in this country, with any inducement to the manufacturer. In a paper read by Mr. T. Aikman of this town, in the month of June last year, before the Congress of the German Chemical Manure Makers assembled at Hanover, he estimated that something like the above large quantity might be made, to deliver in Europe, at about £12, inclusive of the fiscal taxation and freight, which together at that time represented about £5 of the selling price per ton. He stated, however, that a reduction to £10 through the removal of the duty might still bring supplies. If we take the latter figure as the minimum possible selling price in this country our estimate shall not be too high when we consider the depressed condition of the trade in South America at the present time. Now let us look at the relative monetary and agricultural values of the nitrate and the sulphate. With the former at £11 and the latter at £16, there is £5 of difference, which are about the figures at the present time. There are two reasons for this difference; the first

is that the percentage of available nitrogen is respectively 15·65 in commercial nitrate of 5 per cent. "refraction," and 19·76 in commercial sulphate of 24 per cent. ammonia; the second reason is that nitrate, although now very largely used, has been considered incapable in many circumstances of replacing sulphate. There is no doubt that this consideration has been carried too far, to the detriment of nitrate, as recently it has been found to be capable of replacing sulphate to a much greater extent than has hitherto been believed; but even leaving that out of the question, and placing the two articles on the footing of the relative proportions of nitrogen alone, there will always be, with nitrate delivered at £10 per ton, a balance in favour of sulphate of £2 12s. 6d. per ton, bringing it up to the selling price of £12 12s. 6d. The natural condition of things which is thus certain to be brought about is this:—competition in the manufacture of sulphate will by-and-by reduce the price, but not below £12 12s. 6d. (except by flukes), as long as nitrate does not fall below £10. In other words, no one would think of buying nitrate at £10, except for some special purpose, as long as he could get sulphate for £12 12s. 6d. But can sulphate be made to pay at this figure? There is no doubt that it can, and not only so, but it is certain that it will prove one of the most remunerative businesses for the small capital invested that was ever known in the history of chemical industry. It must be remembered that the prospective makers pay nothing for their ammonia; they have the gases free, and with a cost for plant which can be written off with something like six months' profits, and but a comparatively small proportion of the selling price expended in chemicals and labour, there is a fine future in store for those who are fortunate enough to possess these gases.

It may be asked what guarantee producers have, that such vast quantities of this material will be got rid of? The above facts are a sufficient answer. There probably never was in history before so complete an assurance in this respect. They are making an article with a superlative profit, which is clearly capable of replacing an enormous amount of another material, valuable and cheap as the latter may be.

We now approach the tar question. I have all along given my opinion to ironmasters, with whom I had to do, that little or no value should ultimately be counted upon for the tar from blast-furnaces. There are at least three reasons for this—first, the tar, so-called, is of a very inferior character, as compared

with coal tar; secondly, the ironsmelter has no control over this, as he cannot alter his heats in such a way as will improve the tar, but must work under fixed conditions, his primary object being to produce iron; and, thirdly, the coking ovens of the future may, and now certainly will, be built to produce a tar of the highest quality in every respect, and on such a scale as will put blast-furnace tar rather in the shade. We have seen that the improved Simon-Carves coke-ovens yield, even now, 7 gallons of excellent tar per ton of coal coked, or 70,000,000 gallons, if we assume, as heretofore, that even half the coal coked in this country be treated by this method. Supposing this tar to be of average quality, as compared with coal tar, or even less, we should expect from it 5 per cent. of commercial naphtha of ·900 sp. gr.—equal to 3,500,000 gallons, and this with a yield of 20 per cent. of true benzine, would give for the United Kingdom an extra 700,000 gallons of the last-named product. We shall best be able to judge of the effect of this largely increased quantity by comparison with the amount produced in this country at present, taking into account only the coal carbonized for gas in all the principal towns. This cannot be less than 5,000,000 tons of coal per annum, which, at the low average of 5 gallons per ton, gives 25,000,000 gallons of tar, which, with a yield of 5 per cent. of commercial naphthas, gives 1,250,000 gallons of the latter, and if we regard $\frac{1}{5}$ of this as benzole, we have of the latter valuable product 250,000 gallons. But when will this greatest of revolutions take place? Clearly not all at once, for when we consider the vast amount of money, energy, and time which must necessarily be expended before these figures can be realised, we must discern that the end is not yet. A maximum capital of, say £150,000, would put all the blast-furnaces in Scotland in operation, and this ought to produce 20,000 tons of sulphate. A like quantity would be obtained by an expenditure of a similar sum for blast-furnaces working on coal in England, and gas-producers, taken together. All this could be accomplished within a year with ease, the only obstacle standing in the way at present being the inactivity or distrust of ironmasters, who evidently cannot realise the good fortune which is lying at their door, and who, instead of plucking the flower which is extended to their grasp, are manifestly waiting to see whether their neighbours are going to be free of the thorn, which is only too frequently the reward of temerity on the part of those who are in the van of invention. Blast-furnaces should

naturally come first, from the rapidity, ease, and cheapness with which they can be adapted for the recovery of the volatile products. The adaptation of coke-ovens, however, is a more serious matter, as there is not only the erection of the plant for securing the ammonia, but there is the alteration, or, more probably, the renewal of the ovens themselves, which is a much more weighty matter, but not so much so as to be any barrier to its being gradually and surely accomplished. An estimate of the cost of building the new Simon-Carves ovens was given by Mr. Robert Dixon, manager of Messrs. Pease's coke works at Durham, in a paper which he read at the last meeting of the Iron and Steel Institute at Middlesbro'. He puts it at £180 per oven, each oven converting 1·31 ton of coal per day, or 458·5 tons per year of 350 working days. At this rate, in order to overtake our 10,000,000 tons of coal per annum, 21,810 ovens would require to be built at a total cost of £3,925,800—a result which will not be accomplished for years to come, but which, come when it may, will find sulphate of ammonia selling at over £12 per ton, and continuing to do so probably as long as most of us will last, unless a very cheap mode of making it by the direct combination of hydrogen with the free nitrogen of the atmosphere be discovered, and that is not at present on the horizon. We are tempted to look at the prospective profits of this giant industry which is looming before us like a mountain, from whose sides, and even summit, the mists are rapidly clearing away, and leaving us in sight of an object—grand, real, approachable, attainable. Mr. Dixon, than whom none is more competent to know, estimates the *extra* cost of burning by the Simon-Carves oven at the rate of 11·79d. per ton of coal, but states that this covers the expenses connected with obtaining the bye-products, by which I understand the ammonia liquor and tar only. For 10,000,000 tons of coal coked this will give £491,250 expended, more than would have been the case if the coal had been coked by the old methods. To this must be added, say £5 per ton of sulphate of ammonia produced, to pay for sulphuric acid, labour, and plant in its production, or £558,035, which, added to the extra cost of coking, gives £1,049,285, a sum which must be deducted from the total market value of the finished products. These, even taking the 111,607 tons of sulphate at the prospective value of £12 12s. 6d. per ton, and the 70,000,000 gallons of tar at 2d. per gallon, would give, together, £1,992,371, less £1,049,285, leaving a net profit of £943,086, or about 25 per

cent. on the expended capital. This is extremely encouraging, especially when we consider that the ovens will no doubt, before long, both be more cheaply built and economically wrought.

I may mention that I have recently examined a sample of the Simon-Carves Tar, and find that it is a true "gas tar," containing benzole and naphtha, with abundance of naphthaline, and doubtless of anthracene also. I do not think it would be right here to quote the proportions of commercial naphtha and benzole which I found in it, as the sample was given to me by favour, and I am not certain that it fairly represents the bulk of the tar which is being recovered by this process, but I have placed on the table, samples of this tar and of blast-furnace tar for comparison, and also of benzole made from the tar obtained from the former.

At the Southport meeting of the British Association, Mr. J. A. Wanklyn treated the chemical section to an account of Cooper's process for liming coal in gas-making with the object of increasing the yield of ammonia, as well as of gas or tar. His description and details of results are fraught with interest, and point to a large increase in the ammonia, as well as an improvement in the quality of the gas and in the quantity of tar, while the coke, so far from being deteriorated, burns better and gives products of combustion more free from sulphur than usual, the latter being fixed by the lime. The actual gain in ammonia, as observed in experiments on a working scale at Beckton, London, Cheltenham, Liverpool, &c., for an addition of about 2½ per cent. of lime, was not less than one-third, while that of tar in one instance was 13 per cent. The diminution in the proportion of sulphuretted hydrogen in the gas was also most marked—an average of about 3 vols. per 1,000 vols. having been found, as against 12½ vols. by the ordinary method, and that of the bisulphide of carbon was observed to be from about 35 grains, as obtained in the ordinary process, to about 12 grains by the improved one. These experiments, if such they can be called, were made on many thousand tons of coal, and there is nothing more clear than that the introduction of this process points to the abolition of lime purifiers, and may mark an epoch in the history of gas-making, if found to pay. But if it can be applied in gas retorts, why not in coking ovens and gas producers? it is so already, necessarily but inadvertently, in blast-furnaces, the gases of which contain very much less sulphuretted hydrogen, compared with the amount of coal used than is the case where no lime or limestone is employed, and there is every reason to suppose that

they yield more ammonia through the influence of the lime than if that element were absent. But if this process be beneficial in gas-making, why not in coke-making? All coke would be improved thereby, but particularly blast-furnace coke, such as that used for smelting almost universally in England, as there would be practically no restriction as to the proportion of lime employed.

We now take a passing glance at an industry, not perhaps quite so gigantic as the preceding is prospectively, but still of vast importance, and one whose metamorphosis is perhaps quite as complete, and certainly as illustrative of the fact that the application of existing knowledge is frequently as potent a factor in promoting the improvement or development, or it may even be the creation, of a new industry as the discovery of a new principle. I refer to the iodine manufacture. For how many long years was it known that iodine existed in quantity in the mother-liquors of the nitrate of soda of Peru, during the whole of which time the very reactions upon which its present extraction is based were equally well known. It seems almost incredible that so large a quantity of a substance having so temptingly high a price could have been not only neglected, but absolutely thrown away; but the reason why it was so seems equally incredible. It was simply this—that nobody did anything but talk about it, and contradict each other with regard to the possible production. As soon as ordinary skill was brought to bear upon it, however, it yielded a rich harvest, and proved to the world that there was a practically inexhaustible store of iodine to draw upon, and from an entirely new source. But if nitrate of soda be replaced to a large extent by cheap sulphate of ammonia, will this any longer be a source of iodine? Unquestionably it will, as there will always be a large quantity of nitrate of soda in demand for other than manurial purposes, and, with a restricted output, both nitrate and iodine will bring a more natural price; and the displacement of the former will not only be compensated for, but in all probability we shall see it with a higher market value than sulphate of ammonia—a result which it would be difficult at present to induce dealers in these articles to believe in. The curious feature in the history of this new source of iodine is, that, while the nitrate of soda people themselves were probing Peruvian soil for other sources of wealth, such as borate of lime, which is now being wrought there, they were watering it, barren as it is in that part of the country, with

a substance contained in the so-called "waste liquor" which was worth more per lb. than almost any other manufactured chemical product.

Having thus seen how, in many instances, much valuable material has been lost simply for want of the application of existing knowledge or for want of action, let us see whether it is not possible that history may be repeating itself now with regard to some other matters, even in our own country. Within the recollection of all of us, the wood of the primeval forests of America, and, to a small extent, of Europe, with some sea-weed gathered chiefly on our own shores and partly on those of the north of France, supplied us and the world with all the potash we required. The raising of potash salts from the North German deposits has, however, altered that condition of things, and has at once prodigiously swelled both the supply and the demand. The first source is gone, and the next has dwindled to small dimensions, so that we are now dependent chiefly on the last-named source. We cannot estimate the output from this alone at less than equal to, say 125,000 tons muriate of potash per annum. The crude salt or "carnallit," from which the commercial potash salts are obtained, contains but 10 per cent. of potash in the form of potassium chloride. Will it be believed that in our country illimitable quantities of mineral exist containing larger proportions of potash than this, that are awaiting not the advent of some discoverer, but merely a man with a knowledge of chemistry, resources to draw upon, and a determination not to be baffled? It is quite true that in the German mineral the potash is all in a form soluble in water, but this advantage is not so great as it appears at first sight, as the other constituents are soluble also, and hence require to be separated. In the minerals I refer to all is in an insoluble form, but this may be no disadvantage, as if only a solvent could be got for the potash the separation would be all the more easy on that account. If Germany has been favoured with a rich deposit of salts from a dried-up sea, we have in Scotland hundreds of millions of tons of rocks still richer in potash. Some of these—felsites—I have examined, and found to contain as much as $10\frac{1}{2}$ per cent., but, as the samples were taken at random, it is probable that an investigation would bring out some still richer. I am aware that experiments have been made on an extensive scale in this town many years ago with the object of utilising some of these minerals for potash, but the subject was

never attacked systematically, and we have new lights and new resources now which then were not at our command. Mr. Weldon tells us that the rocks which compose the mountains of Saxon Switzerland contain at least 11 per cent. of potash (besides 4 per cent. of lithia). This may not be of much value to the Germans as long as their big deposits of potash salts last, but it may turn out to be of importance to us to have such a mineral here as we have; for it must be remembered that, in addition to the cost of extraction in that country, there is a long railway carriage and freight to this one to pay for the cost of extraction from any suitable mineral here. Already important work has been done in this direction. Mr. John Spiller last year gave us a most interesting account of experiments he was making on the preparation of potash alum from felspar, in which he obtained, even working in a crude way, weight for weight of the felspar employed. In fact, an alum is made in Germany from a mineral containing only from 5 to 6 per cent. of potash by the action of waste sulphurous acid and air, and there seems no good reason why it should not be done in Scotland, where there are millions of tons of waste sulphurous material and "coal brasses" to be had for the lifting. The prospective reduction in the price of ammonia, however, holds out but little hope of the manufacture of alum from this source turning out a commercial success. Even now it would pay much better to use sulphate of ammonia than sulphate of potash for alum making, which always closes up one outlet for German potash and tends to weaken the monopoly. The proper direction to work in, however, would be that of endeavouring to obtain the *ordinary* potash salts which are consumed in such vast quantity. But do we not sin in other ways as regards the waste of potash salts? Wagner, in his "Chemical Technology," translated by Crookes, tells us that in 1868 there were imported into the United Kingdom from Australia and the Cape 62,000 tons of sheep's wool, which contained potash, equal to between 7,000 and 8,000 tons of carbonate, and having a then money value of about £260,000. Not a particle of potash was recovered from this, although that could be accomplished by heat and simple mechanical processes, without the use of any chemicals whatever; and even at the present time not a pound of this is saved. We evidently prefer to pay our Continental friends £20,000 a year for carbonate of potash, made by them from this source alone, rather than take any trouble in the matter.

There is yet another source of loss in potash in this country, which, although perhaps not actually great, is small only because its neglect has prevented the use of the material from which it might be made with profit. I refer to the beet-root molasses used in the distillation of spirit. Two samples of these, which I analysed lately, contained—

	No. 1. Per Cent.	No. 2. Per Cent.
Sulphate of potash,	·15	·13
Chloride of potassium,	2·60	1·97
Potash (comb. with org. acids),	4·83	3·94
Equal to Carbonate of potash,	7·08	5·78

Taking the average amount of potash as equal, for convenience, to 10 per cent. of carbonate, there is lost, for every 100 tons of molasses wrought in this country, 10 tons of this valuable potash salt, the market value of which, at only £20 per ton, gives £200, from which falls to be deducted, of course, the cost of manufacture, which will not amount to more than one-half. But there are probably not more than 2,000 tons of beet molasses used per annum in this country. There can be no reasonable doubt, however, that they would be very much more employed if the profit from the potash salt was forthcoming. On the continent of Europe some 15,000 tons per annum of carbonate of potash of high quality are made from this source; and it frequently happens that, when either the price of beet sugar, or the poor quality of the beet as regards sugar, precludes the possibility of the profitable manufacture of the latter article, the beet juice is turned into spirit and potash salts in preference.

When last I had the pleasure of addressing you, about nine months ago, I proposed the utilisation of the waste heat of blast-furnaces for the recovery of the salts from sea-water, with the object of not only producing chloride of sodium, which could be made into carbonate of soda by the ammonia of the blast-furnaces themselves—obtained on the spot—but also of producing chloride of potassium—a product having 20 times the value of common salt—and of recovering the Glauber's salt, which, if desired, could be obtained in a dehydrated form by the process of Pechiney. Since that time a portion of the waste heat from the furnaces of Messrs. Bell have been utilised for evaporating the brine from the rock-salt deposits in their neighbourhood for the Newcastle market, and Messrs. Bolckow, Vaugham, & Co., Ironmasters, Middlesbro', were at once to follow suit. I am not aware whether any attempt

is being made to recover the chloride of potassium and sulphate of soda from the mother liquors of sea salt, as is done at Aignes Mortes, in the south of France, but reasoning from analogy, probably not.

We are moving on slowly, however, and Mr. Spiller may not be far out in saying, as he does in the article in connection with which his name has already been quoted, that, "like as the American potashes have been to a great extent displaced by the Stassfürt salts, so, in time, it may chance that British sources of potash will take the place of German supplies." It is not long since a coalition was formed among German potash manufacturers to carry matters pretty much as they pleased, and to force their views upon consumers. The wisdom of this policy has been called in question by high authority, even in their own country, but it serves us right for our inanition with regard to our own potash supplies, which we evidently wish to leave a legacy to posterity, untapped, as we found them.

And we are to have another alizarine work at Middlesbro'! Well, with abundance of anthracene from the Simon-Carves tar at their door, and a big home demand, it is hard to say what success may not attend this enterprise, which undoubtedly arose out of a coalition on the part of German makers to carry things with a high hand—a policy always inadvisable, if not positively dangerous, this example being just a repetition of the old Sicilian sulphur policy, which gave rise to the utilisation of pyrites. Let us hope, at any rate, that this new alizarine industry in this country will wipe out the reproach under which we have figured in the eyes of other nations, to the effect that we had to send our crude material to our Continental friends to be made into a finished article by skill superior to our own, and buy it back from them on their own terms, as they were masters of the situation.

But the question arises, how are these defects in our system to be remedied? Much has been said about original research, but is it not better to understand clearly in what way that is to benefit us. I sympathise strongly with the views of a writer to the *Chemical News*, of 2nd inst., on this subject—Mr. F. J. Lloyd. While advocating strongly the necessity for original chemical research, even in purely scientific channels, and admitting that England is far behind in this respect, he points out what most of us must have observed, that much of the so-called original investigation, accounts of which reach us from the continent, consists in

the expansion of an infinite number of trivial points to an abnormal bulk, indicating clearly a want of originality and perception in devising really new and important subjects, and resulting in work which, to say the least, is childishly finical and unsubstantial. He further points out that much valuable original research is carried on privately in England in connection with technical chemistry, which, for obvious reasons, does not find its way into chemical journals at all. Indeed, if the truth be told, we have a plethora of chemical literature, much of which nobody needs, nobody wants, and nobody will read, a great part of it being mere copy and repetition of what has been done perhaps years before. No one cares to know whether the specific heat of the vapour of moniodomethylsulphobenzamine-metachloride at temperatures between 127·75 and 127·93°C, is ·039981 or ·039982, and as far as the present and prospective bearings of that point are concerned it may be left alone, as it is probably of no more consequence than the question of how many spirits could dance on the point of a needle. It is but natural and proper that the most important subjects for investigation should receive, as far as possible, the first attention. Much money is being wasted by certain Governments on trivial matters connected with science, particularly in the direction of supporting Chemical Colleges and Institutions, evidently to turn out chemists in far greater numbers than the world requires, or is likely to require for some time. These poor fellows, while they are at college, must have subjects of some kind, and the poor assistants who have charge of them must cudgel their brains to find subjects for them somehow, and their work must be printed in some journal to make it appear of importance, and chemists are supposed to buy these periodicals, and to pay for the binding of them, and even to lay them past on their shelves, for they cannot be expected to read them, and thus great expense is incurred, which bears but little fruit. Would it not be wiser if the Governments of those countries who pay for the support of these institutions dictated the nature of the subjects, to some extent at least, which were to be investigated; and this could easily be done by a properly appointed committee who knew the important and immediate wants of a country much better than a student in a scientific chemical laboratory. But, after all, a country must not depend too much on the paternal watchfulness of its Government in these matters, and, fortunately, in this country we don't. It must have struck most of us that a large proportion

of the inventions and discoveries of note and value in this country have been made without state aid or support, and frequently by men who have not had the advantage of a scientific education in their youth. If the fostering of the state could be brought to bear upon such men as these—selected by merit—much good might be done, but I fear there is a general tendency rather to bestow on large masses of irresponsible individuals an education in science subjects, up to a certain low standard, and who, very soon after so much of the country's money has been expended upon them, slip the whole thing. Shall we wait, then, for the tardy assistance, which comes weighted with impossible conditions from high quarters? Certainly not. Let every man who bears the name of a chemist, and especially every young man, lay hold of some good subject, which, with a little discretion and advice, he will have no difficulty in being guided to, and let him make it peculiarly his own, and let him but exercise his working faculties on it—incessantly, indefatigably bestowing upon it his choicest thought and skill, and devoting to it all his spare time, "without haste," but "without rest," and he will soon find that what he sowed in toil and anxious expectation will bring forth fruit, after its kind—either in honour or money, or both —"some thirty, some sixty, and some an hundred-fold."

II.—*Technical Education, with special reference to the requirements of Glasgow and the West of Scotland.* By Henry Dyer, C.E., M.A.

[Read before the Society, 21st November, 1883.]

Various papers have been read at the meetings of this Society on the subject of Technical Education, during the past few years, but, so far as I know, these have always been confined to the consideration of general principles or to descriptions of Continental methods, and no one has attempted to sketch such a system as is required for Glasgow and neighbourhood. At a time when a Commission on Technical Education is engaged in taking evidence both in Britain and on the Continent, when the Scotch Endowment Commissioners have completed their labours and their proposals are about to be carried into effect, and when a Scotch University Bill is in the air, no apology is required for again introducing the subject, but this time with the more definite object of obtaining opinions as to the means which require to be taken in Glasgow and neighbouring districts, to enable the directors and managers of their important manufacturing works and their workmen to hold their own in the ever-increasing competition of the industrial world. I have no doubt the Commissioners and the managers of the various institutions will be very glad to have the opinions of the Members of this Society on this subject.

The proposals which I am about to make are not submitted as the only, or even the best, which may be given, but are intended chiefly as a basis for discussion, and I have no doubt they are likely to be considerably modified in the scheme which is actually carried out. When, however, I state that my knowledge of engineering was gained in Glasgow—first in the workshops, shipbuilding yards, and evening classes, and then at the University, in each of which positions I tried to make the most of the opportunities at my disposal—and that since I left Glasgow,

nearly eleven years ago, I have taken the chief part in organising and managing what is now one of the most complete Technical Colleges in existence, I think it will be admitted that I have had sufficient experience of the subject to justify my opinions being at least carefully considered. Moreover, during the past few months I have had opportunities of personally examining some of the chief Technical Schools on the Continent; and I hope to incorporate in my proposals, not only the results of my own experience, but also such parts of the Continental systems as my observation, and discussions with French and German Professors, have led me to believe are suited to our wants and conditions.

The term "Technical Education" has been very much used of late, but I must confess I do not care much for it, as it leads people to consider Technical Education as something like a special subject—in the same way as Mathematics or Astronomy—whereas it means nothing more than an education specially suited to the career of the persons who receive it. Whatever the career of a man is likely to be, it is absolutely necessary that he be taught to think for himself, and any system of education, let it be called liberal or technical, which does not train him to independence of thought must be pronounced a failure. In the excitement about Technical Education care must be taken that the students are really educated, and not merely crammed with facts, figures, and details generally; for, in such a case, their so-called Technical Education is likely to do them as little good as that which was formerly called liberal. All education should be *liberal* in the sense of enlarging the powers of the students, but there is no reason why a great part of it should not be *technical*, or such as has a direct bearing on what is likely to be their chief business in after life. This object was clearly kept in view when schools and universities were founded in the Middle Ages, when the subjects taught were either those directly required for the professions, or were necessary as a foundation on which professional training might be based. But while the world has been moving onwards since those early days, and knowledge has increased, and new professions and callings have arisen, the great schools and universities have continued to afford very nearly the same sort of education as was given when the Church, Law, and Medicine were the only professions, and when there were no trades or other callings which demanded an intimate knowledge of the great world of Nature around us.

It is impossible to draw a line between technical and general, or liberal, education, and that is why I think that it is a mistake that such prominence has been given to the former name. As, however, its use is so common I will continue to employ it in this paper, and will suppose it to mean the training which men require to undergo in order to be fitted to pursue special callings, limiting ourselves, however, in the meantime, to the consideration of those connected with the great industries for which Glasgow and the West of Scotland are so justly celebrated. These industries generally require two distinct classes of men—the directors or managers, and the workmen or tradesmen—and it will be convenient to consider the training required by these two classes separately, although there are no reasons why members of the trade class should not, after completing the curriculum specially arranged for them, be enabled, or perhaps I should say encouraged, to take advantage of the higher training which would fit them to act as managers or directors.

All educational science and history teach us that educational improvement works from the top downwards, and not from the bottom upwards. If the professional schools, let them be called Universities or Technical High Schools, represent a low standard of instruction or examination, or an incomplete curriculum, the primary and secondary schools leading up to these institutions will always be feeble and inefficient. In considering therefore the scheme of education for training men for any profession whatever, the first thing we have to do is to find out what is necessary for those who occupy the highest positions, and make that the standard to which all arrangements lead. I have no doubt some persons will say that this is beginning at the wrong end, but I would advise such to study history, and they will alter their opinion. After the crushing defeat of Jena, the Prussian Government undertook the regeneration of the State through education, and the first thing that was done was the establishment of the great Frederick William University at Berlin: and such was the effect not only in the schools, but also on the other Universities, which had fallen to a low standard, that Germany now leads the world in intellectual progress; and we all know how great an influence the Universities of Britain have exercised on the schools which lead up to them. That such higher institutions *can* be made thoroughly successful in a very short time, my experience in Japan convinces me, for there a College was organised which trained in the various branches of

engineering, and in which the standard reached did not fall very far short of that maintained in corresponding subjects in Germany. Of all places in the world, Glasgow offers the greatest number of advantages in the way of practical training in the various departments of industry; and its primary and secondary school arrangements could easily be modified to afford the preliminary education necessary for students entering an institution for training in the higher parts of their subjects; and the success of such an institution cannot be doubted, if it is judiciously arranged and managed. Other persons will doubtless say, such higher education is not wanted by men who are to be directors or managers of industrial works, nay, that it unfits them for undertaking the duties of such positions. This was not the opinion of George Stephenson, who, notwithstanding his great genius, felt acutely the want of better education, and did all in his power to provide one for his son, nor of Fairbairn, and other self-made men, who were continually lamenting their inability to investigate scientific subjects without the assistance of some of their friends who had been more fortunate. The large number of imperfectly educated men, who, by natural talent and a fair stock of *common sense*, have been able to do good work in engineering, seems to support the view that much higher education is not wanted; but it must be remembered that the conditions under which work is done have altered much within the last few years. In Britain we had the advantage of abundance of raw materials, and had few or no competitors; now, however, our materials are becoming scarcer, at least improved carrying facilities have placed us more nearly on a level with our Continental neighbours, and competition is now so keen in many branches of industry that I am told that a large proportion of the profits are made by utilising what were formerly called waste products, and by taking advantage of economical methods.

We cannot allow the *useful* training of those in charge of our manufactories to fall below that given to managers of similar works on the Continent if we wish to retain our supremacy, for if we do we will soon find ourselves undersold, or be under the necessity of employing foreigners, both of which things have taken place to a considerable extent already.

Observe, I said the *useful* training, for I think a great deal of what is given in Continental schools is not useful. Some of the higher theoretical subjects are not required as means of education, for the minds of the students can be more effectually trained by

subjects which they can understand and apply; nor are they wanted in the practice of their professions, and consequently are soon forgotten, whereas the time spent on them might have been utilised in obtaining a better knowledge of the practical parts of their work. Not that I would discourage such higher theoretical studies in those who had a special bent for them, but simply that they should not form an essential part of the scheme of education of all who enter the profession.

The term "engineering" is wide enough to include all the professions connected with the great industries, and in the college in Japan I arranged for the following divisions being recognised and taught, viz.:—Civil Engineering, Mechanical Engineering, Naval Architecture, Chemical Engineering, Electric Engineering, Mining and Metallurgy, all of which are of great importance to Glasgow and the West of Scotland.

Civil engineering was formerly used to denote all engineering other than military; but the name is now generally restricted to such works as roads, railways, canals, river and harbour works, and to structures generally, as distinguished from mechanical engineering, which is occupied with the design, construction, and use of machines. With the Clyde as the headquarters of shipbuilding, can any one doubt the success which would attend a properly organised institution for the systematic training of mechanical engineers and naval architects, and for the theoretical and experimental investigation of all questions which arise in connection with their work? Ordinary or land architecture is a subject evidently requiring more attention from a great many men who practice it, for I find a well-known Glasgow architect saying—"We have, no doubt, the presumptuous and unscrupulous in every profession; but I question if you will find so large a proportion of the ignorant in any other—of course, I mean ignorant in the sense of being deficient in professional knowledge, through insufficient or inefficient professional training." I have no doubt some members of the profession will protest against architecture being called a branch of engineering, having always been accustomed to regard it as a fine art; but although all architects should study the artistic side of their work, it is a great misfortune that they do not undergo a better training in the fundamental principles of construction, and of physics applied to architecture. If they did, we would have buildings which were not less beautiful, but which at the same time were made to suit the purposes for

which they were intended, and with the parts properly proportioned as regards strength; we would have public halls in which it was possible to make one's self heard without extraordinary exertions, and in which the ventilation was so arranged that when they were filled with people it would be possible to remain in them with a moderate amount of comfort; we would have private houses which were not nests for generating typhoid fever, and in which we would not be stupified by a few hours at a social reunion—considerations which enable us to fairly claim architecture as a branch of engineering. Electric engineering—a subject which is developing rapidly—is now of sufficient importance to be recognised as a special branch (although its applications will soon become so general that all classes of engineers must study them to a certain extent), while the wide domains of applied chemistry, mining, and metallurgy all give opportunities for the application of the highest scientific knowledge, and require a thorough training in those who practice them.

It is impossible to arrange courses of study suited exactly to the wants of every branch of manufacturing industry, but the divisions I have named are sufficient to cover the wide field of what is usually called engineering; and after having completed a course of study in one of those divisions, the students would be very soon able to learn the special details required in their every-day work. The greatest liberty ought to be allowed to those who wish to attend special classes, so that they might supplement some other course, or perhaps only study such parts as their time permitted.

In a paper like the present we cannot enter into the details of the courses for the subjects I have enumerated, but a few of the characteristics which should be common to all may be mentioned. When the students begin them they are likely to be about 16 or 17 years of age, and should have received as liberal an education as possible, and at first should devote themselves chiefly to those sciences which are required for the special branch of the profession which they have selected, giving some of their time, however, to other subjects of a more general nature, such as those connected with literature, philosophy, and art, in order that they may have opportunities of rising above the details of their every-day work, and taking a wider view of life and its purposes generally. Then there are certain subjects which should be common to all the courses, such as, for instance, those on the properties of materials and what is usually called Applied Mechanics, but which I prefer

to call the Dynamics of Engineering, being a resumé of the parts of Dynamics which are specially used in Engineering, and the methods of applying them.

The instruction in the special subjects should not be confined to mere lecturing, which, to a great many students, is very unprofitable. Lectures are useful if they teach the students to think for themselves—if they stimulate to exertion, and give advice which springs from personal experience—if they guard against wrong methods, and give information as to the latest results on any branch of the subject; but it is a waste of time, both on the part of the student and the teacher, if they are confined to a restatement of principles which can be studied in print with greater advantage than from lectures. The teacher ought to use a text-book, and occasionally give a running commentary on those parts which seem to require it; but the greater portion of his time in the class-room should be employed in giving illustrations, and the results of practical experience and of original investigations. The most important part of the work, however, should be carried on in the drawing offices and laboratories. In the former, mere copying of drawings should be prohibited, and everything done from sketches taken by the students, from models or actual machines, or from data supplied by the teachers, all the details of the calculations, however, being made by the students. In the laboratories, experiments should be made to illustrate dynamical principles, to ascertain the properties of materials, and to test the efficiency of engines and other machines; while the electric engineers, the chemists, and metallurgists should have departments of their own, with all the necessary appliances; and the naval architects a tank for experiments with ships' models. To the various departments there ought to be attached small workshops, with a selection of hand and machine tools, not for the purpose of teaching the students the practical part of their profession, but simply to give them an elementary acquaintance with tools, and facilities for preparing their laboratory experiments, and opportunities for making such parts of apparatus as they may themselves have designed. Then there ought to be museums in each department, or a convenient central museum, where the students could spend some of their leisure time in examining well-arranged specimens of raw materials, of products in various stuffs, and of all kinds of machines and engineering appliances. I need not enumerate further at present, as I have already mentioned more than is

likely to be supplied for some years to come; but the system I recommend may be briefly summed up by saying that the professors should endeavour to make their instructions real, by acquainting the students with things themselves, instead of merely giving them information about things.

The examinations, especially those near the end of the course, should be of such a nature as to test what the students know about their subjects, and not, as is very often the case at present, give prominence to the best crammers and the most expert writers. They ought to be placed under very nearly the same conditions as they would be in actual practice—that is, supplied with the necessary data and a few books of reference, and be prepared to show that they are able to apply their knowledge to the solution of practical problems.

So much for the more theoretical side of the students' education, but as much importance must be attached to the practical, for successful engineers are only to be obtained by an intimate combination of theory and practice. Different plans have been proposed for obtaining a knowledge of practice. The most usual recommendation is that the students complete their College course before beginning their apprenticeship, but in my opinion this is a mistake, as it is of the utmost importance that they begin their practical work as early as possible, as it gives them a great advantage in their studies when they have had some experience in the workshops. Moreover, young men of 20 or 21 are not likely to take to what is often considerable (but very necessary) drudgery, as those who are three or four years younger. To get over the difficulty it has been suggested that the apprenticeship should be served before entering College; but on the other hand, I am afraid that few would have patience to begin a lengthened course of study when they were 20 or 21. In Japan I got over these two difficulties by keeping the students at College in the winter and spring months, and sending them out to works during the remainder of the year, and, in addition, requiring them to serve two years under properly qualified engineers, and I think this is the system which ought to be carried out in Glasgow, It may be said that engineers would object to receive apprentices if their time was broken in the way I have suggested, but I think that there would be no difficulty in obtaining employment in workshops if the students went in as real working apprentices, and were paid the market value of their work, and made to understand that their

business was to work, and surely more than ninepence or a shilling's worth (which is the average apprentice wage) could be taken out of young men of 17 or 18. All the classes of engineers I have mentioned would be the better of some experience of this sort, but in the case of Civil Engineering, Architectural, and Mining students, part of their summers might be spent in the practice of Surveying. It must be distinctly understood that I am not now speaking of the great body of apprentices (who will work in the usual manner), but of the comparatively small number whose parents can afford to give them a rather expensive College course. I will delay what further I have to say about apprenticeship till I speak of the training required by tradesmen or mechanics, for this part is common to them, and to those who are preparing for the higher positions.

The next question to consider is—What class of institution or institutions should undertake the instruction in the professions I have mentioned? Is it necessary to organise separate independent institutions, such as the German Polytechnicums, or is it possible to extend the means already in existence for Technical Education in Glasgow to meet the required wants? In Scotland the training for the older professions of the Church, Law, and Medicine, has been undertaken partly by the Universities, and partly by the private schools and corporations connected with those professions, and I think it will be admitted by all who have studied the question that the work has been better done by the two kinds of institutions than it would have been done by one of them. But without doing away with the healthy emulation which should always exist between learned institutions, is it not possible to imagine a University wide enough to include all the higher education in a given district? For instance, could not the University of Glasgow affiliate any institution in the West of Scotland in which the standard of instruction was sufficiently high, whether that was given in Arts, Theology, Law, Medicine, or Engineering, and grant its degrees to those students who passed the necessary examinations?

The classes of the various Presbyterian Theological Halls are already recognised for the degrees in Divinity, and those of certain teachers in the different departments of Medicine for the degrees in Medicine, and all that is wanted is to extend the same privileges to teachers of other subjects who are in a position to satisfy the proper authorities that the instruction they give is worthy of

University recognition. Arrangements could easily be made which prevented teaching mainly directed to enable the students to pass examinations, or "cramming," as it is usually called. I think that examiners are very often more to be blamed for cramming than teachers, as the examinations should be of such a nature that mere cram would count for little; as I have already indicated, I can confidently say that for Engineering subjects its influence could be reduced almost to zero. The general subject of University organisation, however, is beyond the scope of this paper, and I will content myself with simply expressing the opinion that all the higher education relating to Engineering should be given either directly in the Universities, or in institutions in which the teaching is recognised as leading to their degrees.

In the sequel I will use the term "Technical College," as a convenient name for the means by which the higher industrial education is carried on, whether these may be altogether through the University, or in great part independent of it, while the term "Technical Institute" will denote the more general organisation, which includes not only the Technical College, but also the secondary and elementary industrial teaching required for the various trades.

The Endowment Commissioners propose to organise a Technical College in Glasgow, and if the amount of the funds at their disposal was very large, and they knew exactly what was wanted, it might be advisable to found a large institution in which instruction was given in every industrial profession; but I am informed that the money they have to spend would go a very little way towards its erection, and very likely after it was erected it would be unsuitable for the purposes for which it was intended. It is not sufficient to have four walls and a roof as a place for giving, at least, the higher parts of technical education, for each department requires special arrangements in its buildings, and room for expansion as the demands of the public increase.

I have no doubt that fifty years from this, the buildings devoted to technical education in Glasgow will rival the handsome pile on Gilmorehill, and while recognising the advisability of obtaining as suitable buildings as possible, in the meantime let us follow the example of the early Universities, and first create a demand for the newer education before we invest money in stone and lime, which could be used to greater advantage in pro-

viding good teaching and apparatus. A College, or University, is not necessarily all contained within one building, but for success it is requisite that its various parts be so arranged that they all work in harmony. For instance, in the German Universities you often find the most important subjects taught in what are called Institutes, all of which, however, take part in the University programme of teaching.

If the present Glasgow University buildings are not sufficient to give all the necessary accommodation for the higher industrial education (and, I believe, they are not), then other buildings in the town should be utilised, and the instruction given in them recognised as leading to the University degrees. These institutes, as they might be called, would be directly controlled by the University, in so far as the standard of instruction and examination is concerned; but the management of details should be left to men who were capable of advancing their interests, in short, there ought to be local self-government, combined with sufficient centralisation, to prevent any loss of efficiency.

I have no doubt some persons will say that the University is not the place for technical teaching. If that be so, I would ask, what is the meaning of the engineering classes? If they are worthy of a place at all they are worthy of being developed in the way their importance demands. I think no objections are likely to come from the University authorities, as I remember, some years ago—I suppose with their approval—Professor Young inaugurated a class in mining, but which was stopped after a short time from want of support, and at present lectures on marine engineering and naval architecture are given in the University. Some of the younger colleges and universities have courses in the various departments of engineering very fully developed, and a son of a former president of the society, who is now a distinguished professor at Oxford, distinctly recommends such courses for Oxford and Cambridge. Professor Bryce says:—"The Universities do not attract students from all classes because they do not give professional instruction. To give everybody a first-rate general liberal education is a noble ideal for a university. But not everybody has time for such culture, and a university throws away half its usefulness which either refuses professional training to those who have not had a general liberal education, or forgets that professional training, given in a truly philosophical and scientific spirit, may be made stimulating and cultivative, as well as practically useful. It

would be a fine thing, no doubt, to take every lad who was going to be an engineer, or a doctor, or an attorney, through Sophocles, and Kant, and the Differential Calculus. But if that cannot be done, is it not better that the lad should learn his mechanics and law and physiology in a university, from teachers who have an educational as well as a practical end in view, and in the company of fellow-students whose ideas and pursuits are different from his own, and will enlarge his horizon, rather than that he should be warned off because he has not passed through the theoretically best preliminary course? Considering that most men spend all their lives in the practice of some gainful art, it is surely a great thing that they should have been given in their youth a worthy and scientific conception of that art. As it is, the English universities, in the pursuit of this ideal liberal education, have dropped that professional instruction which they gave in the middle ages, and which is still given by their sisters in Germany, Scotland, Scandinavia, and to a considerable extent in America also." The latter part of this last sentence, of course, refers to the systematic instruction given in the universities named in theology, law, and medicine, although, in speaking of Scotland and America, he might have in view the departments of engineering, imperfectly developed as they are; but in the article from which I have quoted he distinctly recommends the institution of professorships in every branch of knowledge, and especially in such practical subjects as engineering, mining, applied chemistry, and agriculture.

The students of engineering should spend three or four winter sessions at the College or University, the summers being taken up in practical work; and those who attained the required standard should be awarded the degree of B.Sc., or, in the absence of that, a special certificate—the degree of D.Sc., or higher certificate, being reserved for those who subsequently passed a higher examination, and displayed original ability. I have said that the average age of the students when entering the Technical College would be 16 or 17 years, which is considerably below that of corresponding institutions on the Continent. For instance, in the Ecole Centrale in Paris the average is between 19 and 20 years, the minimum being fixed at 18. As, however, it is of the utmost importance that the students have an early acquaintance with practical work, I think that sufficient instruction for the great majority of them could be given in the time I have named, but arrangements ought to be made for having courses of lectures by men of experience

in special branches, which could be attended in the evenings by the students who had completed their college course; and encouragement should be given to those who displayed ability for original investigation and higher studies to remain longer at College; but these would generally aim at being professors and teachers and not practical engineers, the proper training of whom would be a most important part of the functions of the College.

Should it be found that insuperable difficulties are in the way of connecting the Technical College with the University in the manner I have indicated, I hope that at least some friendly links will be established between the two, which may be increased as time goes on till complete amalgamation takes place. On the Continent, especially in France and Switzerland, you find the scientific classes of the University dwarfed by those of the Polytechnic School, and a great waste of teaching power and appliances takes place in both institutions, and there is no reason why this should occur in Scotland, where the Universities have always been the chief professional schools of the people.

I think, however, it is probable in the meantime that the opinions of the authorities of Glasgow University will agree with those expressed by Principal Tulloch a few weeks ago when speaking at the inauguration of University College, Dundee (which is essentially a Technical College). While wishing the new institution every success, he said "it was not for him or anyone to say whether the College in the future would seek an alliance with an older University, but the course for it at present was to set itself to its own work in the community, and, in short, to try its own strength. The College would, he believed, find genial soil in Dundee, and what it found to do, it should do with its might." On the other hand, those connected with the Technical College are likely to agree with Lord Dalhousie. When speaking of the advisability of affiliation with a University, he said "it had been decided that, for the present at all events, no step of that kind should be taken. The question was one of those which, if they only gave it time, would eventually answer itself. By-and-by they would see their way clearly, but for the present they did well to reserve their freedom of action. They would learn by experience what they really wanted, and, when they had found that out, it would be time enough to make a move."

The circumstances of Glasgow are, however, different from those of Dundee. We have a University in our midst, while that at St.

Andrews is a considerable distance from Dundee, and it is impossible for students of the new College to take advantage of the University classes, whereas in Glasgow that could be easily done. I agree, however, with Lord Dalhousie that the question of the exact relations which ought to exist between Universities and Technical Colleges is one which, if we only give it time, will eventually answer itself, and I think that the tendencies of the age are all in the direction I have indicated.

Let us now shortly consider how instruction in the various departments I have named might be carried out in Glasgow. The present classes in Civil Engineering and Mechanics in the University should be taken advantage of by all who can afford the time for them, as the subjects there taught give a basis for the different departments of engineering; for although it is necessary to specialise the training of the students towards the end of their course, it is even more essential that they should be thoroughly grounded in principles. It is quite impossible, however, for one Professor to do justice to all the subjects named. In University College, London, which is not by any means a rich institution, there are three Professors for the same subjects, one for Applied Mathematics, a second for Civil Engineering, and a third for Mechanical Engineering, and in addition a special Professor for Architecture, a subject which I believe is partly taken up in the lectures in Glasgow University. In a German Polytechnicum, which is really an Industrial University, you find those subjects divided among twelve or more Professors and Assistants. For instance, in that at Aachen there are four Professors of the different branches of what is usually called Applied Mechanics, while in the department of Civil Engineering there are Professors for each of the divisions of Hydraulics, Bridges, and Roads and Railways, and in that of Mechanical Engineering Professors of the Elements, Theory, Kinematics, and Construction of Machines, and of Mechanical Technology. With the excellent opportunities in Glasgow for practical work there is not the same need for so much specialisation as in Germany, but to make the course of instruction what it ought to be, more teaching power is wanted. The institution of the Lectureship in Marine Engineering and Naval Architecture is an admission of the necessity for some degree of specialisation, but I understand that the present arrangements are altogether of a temporary nature, no proper accommodation existing for the class. It ought to be converted into a Professorship and placed on a more

permanent basis. And here I would remark, that in the German Polytechnicum I have mentioned, Naval Architecture and Marine Engineering are taught by one of the Professors of Machine Construction; and this is as it ought to be, for the one is as much a branch of Mechanical Engineering as the other. The same materials, tools, and appliances are used in the shipbuilding yard and the engine shop, both subjects require the same preliminary training, and every Naval Architect should know a great deal about Mechanical Engineering, and every Marine Engineer a great deal about Naval Architecture, as I think those who have had experience of the subjects will be willing to admit. Not that the training should be exactly the same in every respect, but simply that a great part of it should be common to both divisions of the profession, each, however, going more into special details towards the end of the course. It is a well known fact that the greatest improvements in iron ship-building have been made by men who were trained as mechanical engineers, and it is absurd to continue to look upon Naval Architecture as the same sort of profession as it was when ships were built of wood and propelled by sails.

Some years ago an influential committee, of which Mr. W. Montgomerie Neilson, who has always taken a great interest in Technical Education, was the convener, recommended the foundation of a Technical College, in which there should be (among others) a Professorship of Naval Architecture, Marine and Mechanical Engineering; but in my opinion there ought to be one for the more general parts of Mechanical Engineering which I have mentioned above—paying perhaps special attention to Locomotive Engineering—and another for Marine Engineering and Naval Architecture. The importance of those subjects to Glasgow and neighbourhood requires that they should be well taught, and an Institute near the University, and thus also near the centres of engineering and shipbuilding activity would, if properly arranged and managed, be certain to be a great success. The day classes would represent the higher branches, while those conducted in the evening, either by the Professors, or under their superintendence, would be suitable for draughtsmen, firemen, the higher class of workmen, and I think I may add of captains, as recent events have shown the necessity for these latter knowing something about the principles of the stability of their ships, and the Wreck Commissioner has recommended that they be furnished with the results of experiments and calculations on the subject.

Ordinary or Land Architecture is partly provided for at present in the University, but special Lectureships and, ultimately, Professorships are wanted in that subject—treated both as a branch of Engineering and as a Fine Art. At first, some of the best architects in Glasgow might be induced to deliver Courses of Lectures in the evenings, in some convenient locality—as, for instance, in the College of Science and Arts, so that students who have attended the University classes and were engaged in business during the day might take advantage of them, and, as their numbers increased, more complete arrangements could be made.

Electric Engineering would naturally find its headquarters in the University under the guidance of Sir William Thomson; but here again the difficulty of want of accommodation comes in. I lately visited the Polytechnic in Darmstadt, and I found the space occupied by the Electric department (although it had only been recently organised) was sufficient to require a large building, and the subject is rapidly extending. Could it not be arranged that the students take part of their course in the University and complete it in a special Institute devoted to the more practical applications?

The College of Science and Arts, of which the Principal is an Electric Engineer, might make this its chief subject. Very few of the secondary classes at present held would be rendered unnecessary by this arrangement, and they might all be continued (with, perhaps, the exception of Naval Architecture, which would naturally be transferred to the special Institute for that subject) till at least the Electric department was more fully developed, and then the students might learn their Mathematics, Physics, and Mechanics in some other convenient institution. The applications of Electricity will in a short time be so extensive that not only will the profession of Electric Engineer become of great importance, but, in addition, all classes of Engineers must study the subject to a certain extent, and I should anticipate that the special Institute devoted to it would in a short time become one of the most successful departments of the Technical College.

The present teaching power in the University, in Anderson's College (including the "Young" Chair), and the College of Science and Arts is sufficient for the subjects of Chemistry and Metallurgy; and all that is wanted is a better organisation by which the various parts of the subjects should be fully treated by the different Professors, so that the students might have opportunities not only of

studying principles and analysis, but also their applications to special industries. The students of Chemistry and Metallurgy should be strongly advised to attend classes in Building Construction and in Mechanics, as without these they would often find great difficulty in applying their chemical or metallurgical knowledge.

The teaching of mining has received great attention in other countries, but in the West of Scotland coal and ironstone mining is looked upon as such a comparatively simple business that I am afraid there is not much prospect of a great demand for instruction in the higher parts of the subjects for some time to come at least, the present wants being generally capable of being supplied by evening classes in the mining districts. For those who wished special higher instruction beyond that afforded by the present University classes, I think a lectureship in mining would be sufficient. This could be instituted either in the University, or in the Institute for Mechanical Engineering, where the students could also receive instruction in the machinery used in mines, and in drawing.

The Arts Faculty of Anderson's College has never been very successful, not because the Professors were inefficient, but because their teaching was not recognised by Universities, Faculties, or Presbyteries, as forming part of any course, and all that is wanted to ensure success is some such recognition, while its Professorship of Applied Mechanics could not only be utilised in continuing its present very successful work, but also in affording the necessary instruction in mechanics to the students of chemistry and metallurgy.

My proposals thus utilise the teaching staffs and the buildings of existing institutions; but I hope the representatives of those institutions who may be present will not for a moment think that I have laid down any hard and fast scheme, in which they find they have not the position they have a right to expect. I only wish to show how *a* connected system *might* be arranged without at all insisting that it is the only one, or even the best possible. The only new buildings required are those for the Institute of Mechanical Engineering and Naval Architecture. Kelvingrove Museum has been suggested as a convenient position for this, as the students would have the benefit of the Museum and the University, and also be near the chief works. Would it be too much to expect the town authorities to provide buildings

for this department, and the engineers and shipbuilders of the Clyde the fittings and apparatus? I think the matter only requires to be placed before them to ensure a favourable response.*

The nature of the training wanted by those about to enter the Technical College, and the necessity of properly developing the institutions which are required to give it, have been so fully explained by Messrs. Sandeman and Dixon in the excellent paper read before this Society last session, that it is unnecessary that I should enter into many details at present.

The first object of education is to expand the minds and develop the reasoning powers of the pupils, and a skilful teacher can do this with almost any subject. While recognising the advisability of selecting studies which will be useful to the students in after life, I think that perhaps of late undue importance has been attached to that, at least in the early part of their course, as the mental discipline they receive does not depend so much on the subject itself as on the manner of studying it. There are no reasons why the High School and schools of the same type should not afford all the instruction necessary for students entering the Technical College, if arrangement were made for extending the instruction in some of the scientific subjects, and not requiring all their scholars to devote so much of their time to literary studies. Such schools ought not only to have laboratories for chemistry and physics, and teaching collections of apparatus and specimens, but also workshops in which *all* the more advanced pupils, without distinction of object of after studies, might have opportunities of

* Since the above was written it has been announced that Mrs. Elder has presented a large sum of money to the University of Glasgow for the endowment of a professorship of naval architecture. This noble example should stimulate others to assist in making a really efficient institute of mechanical engineering and naval architecture of the kind I have indicated, for there is not sufficient accommodation in the University for developing the subjects in the manner their importance demands.

Events are moving rapidly. I see from this morning's newspapers that the Council of the Institution of Engineers and Shipbuilders has resolved to endow the present lectureship on marine engineering and naval architecture in addition to the "John Elder" professorship. As I have pointed out, there is room for more than one teacher, but I hope, whatever is decided with regard to these matters, that arrangements will be made for fully utilising the endowments by having something like systematic courses, leading up to each other, instead of similar competing courses, which are certainly not required in this special department.

acquiring a certain aptitude in the use of tools which would stand in good stead whatever positions they might afterwards occupy. This is not to be looked upon as attempting to teach a trade. Such work may be made a branch of liberal education as much as any other subject, for by it the pupils would have opportunities of applying their geometry, of practising their drawing, and generally of adapting means to special ends.

Those who intend to enter the Technical College would find it advisable to continue their general education in pure science and literature till they are 16 years of age; but to those who have no time or inclination for this, such institutions as Allan Glen's (which may be considered a secondary school with a technical division) afford a useful introduction to the subjects required in the chief industries, and everything should be done to extend and organise schools of this class as the demands of the public increase.

The College of Science and Arts is also doing excellent work of the same sort; but if my suggestion of making this College the institute for electric engineering be adopted, and arrangements made for supplying it with laboratories and apparatus as its increasing importance demands, it would soon be found advisable to devote a great part of the energy of the staff to the training of electric engineers, and to the teaching of the applications of electricity to others who require to know them. While, however, making this its chief object, as I have already remarked, it might continue to afford secondary instruction, in other technical subjects for which there would be a great demand, such as, for instance, the elements of construction both of buildings and machines, and of applied chemistry, a knowledge of which is really required now-a-days as a part of the *general* education of all classes of men, whatever profession or trade they may adopt.

It has been said that it is absurd and wasteful to have several institutions close to each other, all giving very nearly the same kind of instruction. I have no doubt that if these were all under the same management, the teaching power might be more efficiently employed in certain respects, but the fact that some subjects are common to all those institutions does not in itself prove that there is any loss of efficiency. Writing and arithmetic are taught in all the Board and secondary schools, because every scholar ought to be acquainted with them; so in a similar manner drawing and mechanics should form the foundation of all industrial training. These are almost the only subjects which are at present taught in

more institutions than one, and in the most of cases the class-rooms are overcrowded, and if a proper system were organised the numbers would in a very short time be greatly increased. It is neither desirable nor practicable that such numbers should meet in the same building and under the same teacher.

The diplomas awarded to the students of the day classes of the secondary technical schools, as well as those of the higher evening classes, which I will mention further on, should be recognised by the Technical College as representing the equivalent of part of the higher course, and thus exempt those who possess them from attendance at its junior classes. It would occupy too much of your time to sketch courses of study for these classes, but as it would be advisable to take advantage of the pecuniary assistance given by the Science and Art Department, and the City and Guilds of London Institute, it would be necessary to select the subjects in great part from their programmes. That, however, is a matter which can be easily done when the general lines of procedure have been decided.

As a rule, those who begin work as apprentice mechanics or tradesmen will have received their education in the ordinary Board schools, and there is not very much prospect of the nature of that being materially altered for a considerable number of years to come. The average age of those who leave such schools is not more than 12 or 13 years, and although it is not advisable to attempt too special a training before that age, what I have said about the higher education applies with special force here—namely, that means should be taken to make the education real, by allowing the pupils to study things themselves when that is possible, instead of merely giving them information about things. The practice of drawing ought to be encouraged, not by copying from badly arranged sheets, but by making it a real educative as well as useful exercise. The ability to draw is almost of as much importance to a workman as the ability to write, and the study of drawing should receive a proportionate attention in the elementary schools. The great mistake that is made in teaching drawing is looking upon it too much as a branch by itself instead of making it the graphic expression of other branches. All the geometry required by ordinary workmen might be taught without the use of a text-book, simply by means of a few models and blackboard diagrams, a pair of compasses, and a straight edge, and set square. The drawing of sketch maps should be one of the chief means used in

testing their knowledge of geography. Problems in arithmetic, algebra, and physics are often capable of graphic illustration, while the furniture of the school-room, and the school itself, could afford examples for practice in the drawings used in ordinary construction. A small workshop, in which the older pupils could spend a few hours a week, would give them opportunities for applying and illustrating what they had been taught in the class-room. I need not enlarge on this part of the subject, as properly trained teachers could easily suggest many applications of drawing, but I am afraid the greatest difficulty would be experienced at first in finding such teachers. This has been the case in France, where they are now attempting to carry out such a method as I have suggested, and a special Normal School has been provided in Paris for supplementing the ordinary training given to the elementary teachers, and also for training teachers of special subjects.

My remarks about the teaching of drawing in such schools, and also in those of a higher grade, are not to be interpreted as meaning that special art teachers are not required in some cases, but simply that teachers in every department should be qualified to show their pupils how a great many parts of their work might be illustrated graphically.

No doubt it will be said that even although the teachers of Scotland were both able and willing to give the kind of instruction I have mentioned, the requirements of codes and examinations would prevent them from attempting it, and according to present regulations this is true; but surely there is no finality even about revised codes, and these must yield as public opinion on the subject improves, and a system which seems to be arranged not so much for the advancement of the pupils as that the teachers may obtain a payment for the brilliant feat of enabling them to pass examinations must be considerably modified.

The pupils, after leaving the Board schools for the workshop or manufactory, should be encouraged to attend, first the evening classes for general subjects, which are now so common, and then those for technical subjects which may be instituted, or already exist in various parts of the city, and those who have completed a regular course should receive a diploma, while the most distinguished would afterwards attend the higher classes of the Technical College. For these, bursaries of say £20 to £25 a year should be provided, the object being to assist those who had proved that they were both able and willing to assist themselves. Those who were

neither able nor willing to do this had better be left alone as workmen, for good workmen are to be preferred to a class of men who are too proud to soil their fingers, and yet are not qualified to undertake any higher work. On the other hand, it would be found that generally the men who had passed through the workshop and evening classes to the Technical College were the best in the College, as they would have more experience, self-reliance, and determination than the younger and richer students over whom they would soon doubtless exercise considerable influence. Lord Reay, in a speech which he delivered some time ago, remarked that when he was at school he owed more to those friends of his who were brought up to earn their livelihood, on account of their earnest method of work, than to his teachers, and I have no doubt some of the students of the Technical College will have a similar experience.

The question of evening classes for working boys has been very much discussed of late, and while recognising the advisability of keeping them at a day school till they are physically able to undertake light work, and have received the average education of their class, I think that there is a danger of keeping them sufficiently long (at least with the present system of teaching) to give them a distaste for work, and make them willing to starve on the pittance usually paid to clerks, rather than fit themselves to earn the wages of skilled workmen.

I read somewhere a short time ago that an employer of labour advertised on the same day for a skilled workman for a situation where he might earn £4 per week, and for a clerk at £80 a year, and for the latter post he received sixty times as many applications as for the former, and I have no doubt some in this room have had similar experiences. In Germany and France I recently heard complaints from employers on the same point—they could find plenty of men for the positions of clerks, but good workmen were daily becoming scarcer. I think a great deal of unnecessary compassion is spent on those who are expected to attend evening classes after a fair day's work, as to the earnest student it is no hardship, but rather a pleasure; in fact, a day in the workshop is a better preparation for an evening class than a shorter day in the drawing office or counting house, a conclusion which I have arrived at from personal experience and from that of fellow-students. I suppose apprentices have not changed very much since I was one, for then I observed that the great majority spent their evenings in

ways which were much more injurious to both mind and body than if they had attended evening classes. It must be remembered that the great majority of working boys will become working men, and remain working men; and our efforts should be directed in such a way as not only to enable the ambitious to escape from this position, but what is of much greater importance, to improve and ennoble the workman's life, that the whole class may rise in comfort and security, and still more in intellectual and moral attainments.

A considerable amount of literature has lately appeared both here and on the Continent, treating of that part of a workman's education which fits him to perform the actual manual operations of his trade. I have carefully studied this, and have also observed what is being done on the Continent, but will only take time to give the results of my observations, as details would fill a lengthened paper. In France, Apprenticeship Schools have become very popular; but whatever arguments may be brought forward in their favour, and it must be confessed that some are very strong, I do not think it necessary to discuss them here, as I feel that such schools are not yet within the range of practical politics in Britain. Apart altogether from the capital expended in fitting out one of the best known of these schools, that at La Villette, Paris, the annual cost of instruction of each apprentice is about £11, all of which is paid by the town. Suppose such a school were proposed for Glasgow, is there any prospect of the citizens agreeing to pay for its erection, fittings, and annual expenditure? I think not the slightest, for they would probably say they were being taxed for the benefit of the employers of labour, which, however, would scarcely be true, as the apprentices would be under no obligation to work in Glasgow after leaving the school, and even if they did, the force of competition would prevent the employers of labour being specially benefited by the arrangement.

The only system which has any chance of success in this country is a modification of the old form of apprenticeship, combined with education in such schools as I have mentioned for the different classes of apprentices. If they had acquired a certain facility in using ordinary tools before entering the workshops, and if they continued their studies in the evenings during their apprenticeship, there are no reasons why at the end of it they should not be good workmen. Although we cannot expect employers to start schools in their workshops, still a little encouragement on their part would go a long way towards removing all discussion about the training

of apprentices. If the foremen and leading men were told to pay a little more attention to them, to give them an occasional word of advice, and to distribute a few tickets of admission to the evening classes to the most industrious, and, lastly, if no lines of apprenticeship were given till the young men produced evidence of being able to draw fairly well, and knowing a little mathematics, and the simplest parts of the theory of their work, we would very soon hear the last about inferior workmen. The payment of wages is not a full equivalent return for service, for, as Carlyle said—"Cash never yet paid one man fully his deserts to another; nor could it, nor can it, now or henceforth, to the end of the world;" and everything should be done to cultivate mutual respect between employers and workmen, and a loyal interest in each other's prosperity.

Although I have insisted on the necessity for making arrangements for the higher technical education, and for proper secondary schools to prepare students for it, there can be no doubt that, for some time to come at least, the greater part of technical instruction will be given in the evenings to those who are engaged in work during the day, and this fact must be clearly kept in mind in arranging any system. The teachers of the higher subjects might have some of their lectures late in the afternoons, and also have a few classes in the evenings; but too much evening work must not be expected from them, because a teacher who does his duty during the day requires his evenings for study. The work of such classes should be carried on under their superintendence, but the teaching ought to be done in great part by properly qualified assistants who were not fully occupied during the day. Then, again, those assistants should not be expected to teach many different subjects, as you sometimes see attempted at present. They might take the same subject two nights a week in schools in different localities. For instance, there are no reasons why elementary evening schools in mechanical engineering and naval architecture should not be conducted in the west-end of Glasgow (say in Kelvingrove Museum) and in Govan by the same staff, simply by having different subjects on different nights. Similar arrangements might be made for the other departments in the northern, southern, and eastern districts, while the evening classes of Anderson's College, the College of Science and Arts, and Allan Glen's Institution would supply what was wanted within a radius of two miles from those institutions. It would be possible for the

teachers who teach in more schools than one to carry about with them, or cause to be carried, some of their diagrams, and perhaps a few special apparatus; but this could not be done to any great extent, as I do not require to tell those who have had any experience of the matter. Nor is it necessary, for in elementary classes, such as are wanted by ordinary tradesmen, a great deal can be done with small teaching collections of models and specimens, and the students of the secondary and higher classes could attend the institutions I have named above.

The whole programme of the City and Guilds of London Institute might be fully represented in Glasgow, not necessarily by special schools, but by classes in schools, which also afforded the students opportunities for instruction in general subjects. We have one special or trade School in Glasgow, the Weaving School, which has been very successful so far as its means would admit. Establishments of this type are of the utmost importance to the industries they represent, and are not to be looked upon as apprenticeship schools, for they cannot supply the need of actual experience in the manufactory, but only afford instruction which enables the pupils to take advantage of what is to be learned there. They ought, however, not to be so isolated as the Weaving School is at present, but should be connected with institutions which give instruction in drawing and designing, the elements of mechanics, and some branches of general culture. No doubt the students of the Weaving School, and schools of the same kind which may be organised, can obtain such instruction by attending classes in other parts of the city, but the subjects necessary for the different trades should be arranged in convenient groups, so as to save as much time to the students as possible.

In the scheme which is inaugurated, arrangements should be made for connecting schools in the West of Scotland generally with the Technical College, and these schools would send up their best pupils to undergo a higher course of training. For instance, in Dumbarton there ought to be a school for mechanical engineering and shipbuilding, and a similar one in Greenock; the Coatbridge and Wishaw districts ought to have schools for miners and metallurgists; while in various parts of the country there should be schools for bleaching, dyeing, and calico printing, and the different branches of the textile and art industries. In connection with the latter the Haldane Academy and School of Art has been doing excellent work of late, and local branches (similar to the one

in Bridgeton) ought to be established where they are likely to be successful. I would remark, however, that it would be advisable to leave the various branches of *engineering* drawing to those institutions which give instruction in the principles required in working designs, as engineering drawing taught simply as a Fine Art is not likely to lead to much good.

No system can be considered complete which does not include instruction in agriculture. It was remarked by some one, when the Agricultural Holdings Act was passed, that for the first time in history Parliament had anticipated what science had to teach us. In America, where land is abundant, Agricultural Schools and Colleges have made rapid progress; but in Scotland, where it is scarce, there is not a single institution of this kind, and yet our farmers wonder why their business has not paid well for some years past. I need not, however, enter further into details at present, as any system, to be successful, must be built up bit by bit, as the demands for the newer education increase, and an elaborate scheme drawn out now would be of little value. What is wanted is that the general lines of procedure be clearly marked, and that a few men imbued with a real missionary spirit be enlisted to organise and assist in the superintendence of the work in any locality where it was likely to be wanted.

At present Glasgow University has three chief grades of examinations, the first for degrees for those students who have attended its classes, or those of teachers recognised by it, and the second and third for the senior and junior certificates for pupils of secondary schools which are not connected with the University, and a similar system is required for industrial subjects. The Technical Institute, assisted by representatives of the various branches of the engineering profession, and of the chief trades, should award diplomas of three classes, the first, to those who complete the course at the Technical College, would represent the professional class; the second, to those who complete the secondary technical and the evening classes, who would generally be draughtsmen and foremen; and the third, to those who took the junior and the special trade evening classes, who would generally be workmen. The examinations for these diplomas should not be competitive, that is to say, there should be no attempt to place the students in the different classes in the order of merit, the standard being fixed to represent the minimum which should be required of the various grades of the different subjects. We have quite enough of competitive

examinations at present, and nothing should be done to increase the number; those who wish special honours have sufficient opportunities for distinguishing themselves. When candidates present themselves for their diplomas, advantage should be taken of any other examinations they may have passed—those, for example, of any University, the Science and Art Department, and the City and Guilds of London Institute—to relieve them from further examination in the same subjects.

The authorities of the Technical Institute should keep a register of all the classes which have been recognised as giving instruction, suitable for the different grades of students as higher, secondary, and elementary; and they should exercise the same authority that the School Board does in the matter of fees, that is, they should fix their amounts for the different grades. Let these be arranged at rates which would bring fair incomes to the teachers, and which are not likely to press too heavily on the students, as it is demoralising to all concerned to have something like a Dutch auction going on to tempt students to the classes. The subjects should be arranged in groups to suit the diplomas I have mentioned, and students should have the liberty of selecting their teachers for any part of the programme, and not be compelled to take all their classes in the same school. This would have the effect of placing the teachers on their own merits, by making their success depend on their ability to teach, and would also prevent the different institutions wasting their energy by attempting to make themselves quite self-contained.

Such is an outline of the system I propose, and what is necessary to make it successful? Of course, a certain amount of money is wanted, but the chief thing is to get the employers of labour and the workmen aroused to the necessity for improved instruction. If no apprenticeship lines were given to workmen who were not able to produce third class diplomas, if draughtsmen and foremen were expected to possess diplomas of the second class; and if the representative institutions of the professional parts of engineering required from the candidates for their membership diplomas of the first-class (except in those cases in which great ability had been shown in some other way), then we would soon find the various schools and colleges crowded with students. I quite recognise the difficulty of making such a system obligatory as a condition of employment, but in a few years it might be in full operation simply as a result of enlightened opinions on the subject.

I suppose if I were suggesting that it should be made obligatory, either by the employers or the employed, I would be accused of wishing to infringe freedom of contract, and of violating the principles of political economy. I think, however, recent events have shown us that the abstract principles of political economy are not the sole guides to be followed in practical legislation.

The Ecole Centrale des Arts et Manufactures in Paris is a wondrous example of what can be done when people are in earnest about education. It has all along been a self-supporting institution, and not only that, but it has saved sufficient money out of its revenue to pay a large part of the cost of the magnificent new buildings which are now being put up for it. At present it has about 600 students, and more than 100 applications from properly-qualified candidates for admission are declined every year, simply from want of accommodation, and there are now in France 3,400 of its graduates in charge of engineering works of all kinds. This is independent of those who have studied at the Government institutions such as the Ecole des Mines, the Ecole des Ponts et Chausees, and others. M. Cauvet, the director of the Ecole Centrale, has published a pamphlet giving its history and many interesting particulars, and I have no doubt he would be glad to send copies to members of this Society who would like to study it.

Are there any reasons why the Technical Institute of Glasgow should not be as successful as the Ecole Centrale of Paris? If properly organised and managed, it ought to be much more so, for there is no place in the world where such opportunities for practical work are to be found as in Glasgow. But every reasonable scheme of reform tries to develop and repair, to build upon old lines when possible, and not to startle by wanton novelty of arrangement or structure. I have tried to show that what is required for technical education in Glasgow may, in great part, be obtained by an improved organisation and an extension of existing institutions, without much expenditure for buildings. The Technical Institute of Glasgow (or, as I would prefer to see it named, of the West of Scotland) should be a corporation, which, taking advantage of existing institutions, in so far as they served its special purposes, supplemented what was awanting in them, so that together they might afford the instructions necessary for the different industries, and by the standard maintained in its higher departments indirectly controlled the teaching in the secondary

schools, which aided both pecuniarily and by sending them properly-qualified teachers, such schools as afforded instruction chiefly to the working classes in the principles which they applied in their every-day work; all the various kinds of institutions, forming not a heterogeneous lot of separate atoms, but a well-ordered system by which the educational wants of every section of the industrial community might be properly supplied.

In order to concentrate the discussion, I will sum up my proposals in the following recommendations:—

1. That a Technical Institute be founded which shall superintend all industrial education in Glasgow, and form a centre for that of the West of Scotland.

2. That it include representatives of institutions of every grade of education—from the University to the primary school—so that a connected system may be arranged whereby students who distinguish themselves in the lower grades may have opportunities of proceeding to the higher.

3. That it take advantage of existing institutions which at present give technical education, supplementing them when they are deficient, and arranging their courses so that there may be no waste of teaching power.

4. That the higher or professional parts of industrial education be given either in the University or in Institutes which have been recognised as giving instruction leading to its degrees.

5. That the curricula of the Secondary Schools be modified so that they afford more thorough instruction in physical science, and thus prepare students who intend to study the higher parts of the subjects.

6. That Secondary Technical Schools be founded which will afford an introduction to technical training, to those who have not time for the higher courses.

7. That corresponding Secondary Technical Instruction be given in evening classes to draughtsmen, foremen, and the higher class of workmen.

8. That Elementary Technical Instruction be given in evening classes to workmen.

9. That for the most part the practical training for the different trades be given in the workshops or manufactories.

10. That for certain trades which admit of it (such as Weaving, Dyeing, &c.), this practical training be supplemented by instruction in special schools or classes.

11. That three grades of Diplomas or Certificates be awarded by the Technical Institute—the first for those who aim at being managers or directors, the second for draughtsmen and foremen, and the third for workmen.

12. While recognising the actual workshops or manufactories as the chief places for practical training, that the instruction in the schools of the various grades be made thorough by the institution of laboratories, museums, and small workshops, which will give the students opportunities of making themselves acquainted with things themselves, instead of simply listening to lectures about things.

III.—*Discussion on* Mr. Dyer's *Paper.* By E. M. Dixon, B.Sc., Principal of Allan Glen's Schools.

[Read before the Society, 5th December, 1883.]

The summary given by Mr. Dyer at the end of his paper of the recommendations it contains will, no doubt, assist us very much in discussing it; and, as an opening of the discussion, I now wish to run rapidly over the leading points in these recommendations, and to indicate briefly my views regarding them.

The first three recommendations in the summary referred to are taken up with the constitution and functions of what he calls a Technical Institute for Glasgow and the West of Scotland generally. This Institute is to "include representatives of Institutions of every grade of education—from the university to the primary school—so that a connected system may be arranged whereby students who distinguish themselves in the lower grades may have opportunities of proceeding to the higher." As to its functions, it is to "superintend all industrial education in Glasgow," by taking "advantage of existing institutions which at present give technical education, supplementing them when they are deficient, and arranging their courses so that there may be no waste of teaching power."

As sketched out by Mr Dyer, this Institute is practically to be an amalgamation of the University, the School Board, and the various trustees of all the educational endowments in Glasgow; and the business of this body is to see that adequate provision be made for instruction in technical subjects in the University and in all the educational institutions and schools of Glasgow.

I am somewhat at a loss to know whether Mr. Dyer makes this proposal as one that should be adopted now and at once, or as one that should be kept in view for adoption when financial and other

circumstances become favourable. If he means that what the friends of technical education in Glasgow should set about at once is to have a Board such as he indicates constituted and armed with the necessary authority to do the work he has assigned it, then I must express my disbelief in the practicability of his suggestion. On the other hand, however, if he means that he is prepared to wait for the development of such a Board out of the educational bodies that at present exist largely in a state of divided effort, and that he wishes now merely to put upon record, as it were, the end to be aimed at, then I can express approval of his suggestion, so far, at least, as regards the general idea of having the Board constituted so as to ensure co-ordination and gradation of technical teaching.

For the present, as it seems to me, all that can be done is to render as efficient as possible the existing institutions in Glasgow, in which technical instruction is given. The amount of money available at present for the furtherance of such teaching does not allow, in my opinion, of more than that being done. Besides, even if there were no financial difficulties in the way, I believe that technical teaching is as yet so new a subject, that it would be unwise to commit ourselves at present to large and expensive schemes. It is also desirable that the growth of institutions for technical teaching should be in reasonable proportion to the numbers of the pupils or students who wish to receive it, the supply being indeed always such as not merely to meet the demand, but to stimulate it more or less, but at the same time not so much out of proportion as to involve serious waste of teaching power and money. Our industries must after all be our guides with respect to technical education. The demand for technical instruction of a kind that really meets the wants of those engaged in industry will, we may be sure, continually increase; but as a matter of practical management, it is right, while the direction in which the demand may declare itself is imperfectly known, to proceed tentatively, and in accordance with the demand.

Following out these ideas for a moment into details, I would say that, for the present (1), a not very numerous Committee or Board should be formed out of the existing managers of Anderson's College, of the College of Science and Arts, of the Weaving and Dyeing School, and of Glen's Institution, representatives from the University and public bodies being added to the number, in accordance with the Scotch Endowments Act; (2) that this Board

should, as far as the means at its disposal permit, equip in every necessary way the four institutions now named for the efficient teaching of the technical branches at present chiefly in demand in Glasgow; (3) in particular, that the number of pupils in the day classes of Glen's Institution, having now outgrown the accommodation, and the establishing of a well-graded system of evening classes in Glasgow requiring a good supply of lecture rooms, class rooms, laboratories, drawing rooms, and workshops in the city, the buildings of Glen's Institution should be extended so as to utilize all the ground at present belonging to the Trust, whereby accommodation would be secured for 600 day pupils and about 700 evening pupils; (4) that, in accordance with the fact that we have already in Glasgow a considerable demand for technical instruction in evening classes, the Board should organise a set of evening classes that would enable apprentices, and young men generally, not merely to receive efficient instruction in the elementary stages of a good many branches of technical study, but should also enable them to carry out a properly graded course of study in the higher branches, to such an extent at least as would enable an ordinary student to make his own way afterwards, if he wished to become exceptionally well acquainted with some department of study; (5) that, in order to allow of the necessary arrangements for accommodating so many evening classes, both in different subjects, and in different stages of the same subjects, the Board should treat Anderson's College, the College of Science and Arts, and Glen's Institution as being each of them tantamount to so many class rooms in one and the same institution, and should arrange for a certain sum total of classes being conducted in them, so as best to meet the conveniences of the students; (6) the Board should not shrink from establishing advanced as well as elementary classes on account of the fact that the advanced classes would be very far from being self-supporting, neither should it seek unduly to render the elementary classes self-supporting, by taking advantage of the larger numbers of students in the elementary stages, to the extent of crowding these classes beyond the limits of efficient teaching, but it should regard the endowments at its disposal as specially fulfilling their intended object when employed, as in this case they would be, to supplement the defective means of students who aspire to a sound knowledge of the principles of their trade or profession, but are unable to meet unaided the necessary expense; (7) that the Board would do the greatest amount of

public good, that is, it would be able to establish the greatest number of useful classes, if it took full advantage of the terms offered by the Science and Art Department, and by the City and Guild's Institute of London; and, assuming that this were done, I think it probable that, in two or three years Glasgow would have in its midst a valuable set of evening technical classes, largely, no doubt, of an elementary character, but yet many of them more or less advanced, and attended by from 2,000 to 3,000 students in the aggregate.

Coming back to the consideration of Mr. Dyer's recommendations, I have to express my entire concurrence with him in the opinion that the higher parts of technical instruction should continue to be given in the University or in institutions under its auspices. I think it would be a serious mistake to set up, on the one hand, any institution for the higher learning to act as a rival to the University; but, on the other hand, I think it would be an equally short-sighted policy on the part of the University to withhold its recognition from any institution that possessed the necessary appliances for doing well what is really University work, and which had come into existence through the very fact that such work was not being carried on by the University. I think we have a clear case in point in the Chair and Laboratory for Technical Chemistry, founded by the late Dr. Young, of Kelly. This Chair unquestionably supplies one thing that is wanting to give even a moderate degree of completeness to the means of chemical teaching in the University of Glasgow. I do not need to tell members of this Society that, at the present day, one Chemical Chair is preposterously inadequate to represent the now enormously extended field of chemical science; and it would, in my opinion, show something like perception on the part of the University of the altered circumstances of the day if it sought to foster, as far as possible, such a chair by at least recognising its teaching as qualifying, so far as Chemistry is concerned, for its degrees in science.

I am not sure that I can express unqualified agreement with Mr. Dyer regarding his proposed treatment of secondary schools. As I understand him, he would insist on all such schools being amply provided with the means of teaching physical science—under which term he would, I presume, include chemistry—and that he would introduce these subjects into the regular course of study for all the pupils who remained at school sufficiently long to reach the higher branches. His idea seems to me somewhat inconsistent

with the freedom of choice of subjects that should exist in secondary schools. In large cities, such as Glasgow, there should be, in my opinion, a few secondary schools of the type of the old Grammar School—that is, schools in which the study of language is the chief educational feature; and there should also be a few secondary schools of the modern type—that is, schools in which the study of science forms the distinguishing feature. In small towns, where only one secondary school could exist, it would be necessary to arrange its classes so as to allow pupils to pursue, after a time, either a course of classical study or of scientific study. Schools of this kind I would, however, only introduce where the organising of separate schools of the types mentioned is impossible. I believe that division of labour is a good principle in school organisation.

What Mr. Dyer calls secondary technical schools are, I imagine, not materially different from the schools I have referred to as secondary schools of the modern type. He instances Glen's Institution as being one of several such schools that Glasgow will eventually have to be supplied with. He assigns to these schools the function of giving technical instruction to boys who have not time for the higher courses—that is, for boys who will not afterwards proceed to the University. On the contrary, such schools as Glen's Institution are, in my opinion, the very schools in which lads will be best prepared for the study of advanced technical subjects in the University, and I am disposed to put down such preparation as an important function of these schools.

Mr. Dyer seems to propose in his seventh and eighth recommendations that two distinct sets of evening classes should be organised—the higher for "draughtsmen, foremen, and the higher class of workmen," and the lower for "workmen." I have already expressed my views about evening classes, and need only say here that without making any distinction of persons, and without hampering myself with the working of two distinct sets of classes, I would simply organise, as I have already said, evening classes in various stages of each of the technical subjects at present chiefly in request, and having thus provided for the requirements of all, whether draughtsmen, foremen, higher workmen, or common workmen, I would finally give them the opportunity of consulting as to their choice of classes, with a man experienced in that kind of education, and then leave them to judge for themselves.

With Mr. Dyer's 9th and 10th recommendations I entirely agree,

and I have, indeed, on former occasions advocated the same before this Society. It seems to be now tolerably clear to all who take an interest in technical education, what, on the one hand, is the function of the school in the training of lads who are intended for industrial pursuits, and what, on the other hand, must be left for them to acquire in the workshop. At first we had a reaction against the total neglect of technical training in schools, during which the advocates of the school exaggerated its capabilities, and proposed to do in it what can either only be done at all, or at least can be much better done, in the workshop. But ideas have become clearer, and I do not believe that there is now much chance of our technical education suffering from errors being made in this respect. The utility of workshops in connection with schools, when used for the purpose of developing manual skill on the part of the pupils, but not with the view of teaching them trades, is now very generally conceded, and it seems to me that such school workshops are destined to become very general within a few years. In schools such as Glen's Institution, a workshop is indispensable in connection with the teaching of subjects of an engineering nature. Without a certain amount of practical experience, it is impossible for a student to understand and appreciate fully much of the instruction he must receive in machine drawing and applied mechanics. It was, indeed, this idea more than any other that first led me to propose to the trustees of that school the introduction of a workshop into our list of school appliances. The idea has been taken up by the managers of several schools in England and Scotland, and, I believe, I may almost say that a school workshop is now one of the recognised class rooms of a school that is intended to prepare lads for entering upon their apprenticeship as engineers.

One or two good workshops should be included in the appliances provided in connection with the system of evening classes I have sketched out. There are many young men, I am sure, who would take advantage of them during the winter months. Amongst others, many young men who have thoughts of emigrating to the colonies, and know that the ability to turn their hands, though only imperfectly, to any common mechanical job that offered would be almost invaluable to them in colonial life, would be glad to avail themselves of the opportunity of learning the use of tools in the workshops I now propose to establish. I may say that a large workshop, capable of accommodating from 40 to 50 students

at one time, might be had, if the buildings of Glen's Institution were extended as I have already suggested.

As to the other recommendations made in Mr. Dyer's paper, I do not know that I have anything of importance to say, and I have only to state, in conclusion, my opinion that the Society has to thank Mr. Dyer very much for bringing before it a paper so full of good suggestions at the present time.

IV.—*On Geography and Ethnology: What these embrace.* An Opening Address by W. G. BLACKIE, Ph.D., F.R.G.S., President of the Geographical and Ethnological Section.

[Read before the Society, 5th March, 1884.]

IN appearing before the Philosophical Society for the first time as President of the newly-formed Section of Geography and Ethnology my first duty is to thank the members (which I now do very cordially) for the compliment paid me in electing me to so honourable a position, and also for electing the able committee at whose head it has been my good fortune to be placed. I can assure the meeting, with very great confidence, that our united efforts will be freely given to promote the objects the Society had in view in forming this Section, and I trust, as the result of these efforts, that a number of interesting and useful papers may from time to time be placed at the disposal of the council.

The formation of a new Section is somewhat analogous to the annexation of a new territory. It opens up an additional field of inquiry which is cultivated by a special class of minds, whose contributions to the general stock of knowledge are fitted to widen the interest taken in scientific studies, and to impart a grateful variety to the Society's proceedings.

Geography is usually defined as being "a description of the earth," a definition which, though very comprehensive, does not include the whole area open to investigation, or convey a very precise idea of what is comprehended in the study which it purports to describe. Properly understood, Geography includes the study, not only of the land which forms our dwelling-place, the waters which furrow its surface and lave its shores, and their inhabitants, animal and vegetable; but also of the vast gaseous envelope in which the globe floats in space, and of the heavenly bodies among which it circles and of which it forms a unit, receiving and reflecting, in common with many other such bodies, the light and heat it derives

from the great central orb of the solar system. This wide subject of inquiry may be divided into two great branches, Physical Geography, or the Geography of nature, and Political Geography, or the Geography of Man, in discussing the details of each of which there is a great liability to trespass beyond the boundary line which separates the one from the other. Ethnology, which finds a place in the designation of our Section, forms in reality a subdivision of Geography, and in some of its aspects may be said to belong to the former great division and in others to the latter, but on the whole chiefly to the latter.

While there is a general agreement respecting what constitutes Geography, yet when we come to examine the definitions of this subject given in the works of eminent writers, we find a want of concord in details, which would cause great surprise were not the area of study so vast, and the component parts so complicated and apt to interlace one with another.

Let us direct our attention in the first place to Physical Geography, or the Geography of Nature, and endeavour to ascertain what its study really involves, as shown by the definitions given of it by some eminent writers.

This great division of geographical study is of comparatively recent origin. Passing over earlier notices, we may begin with the definition of the subject given by Humboldt in his *Cosmos*,* published in 1844, a work which gave great impetus to this study, if, indeed, it may not be said have been the first to bring it into general notice, and to establish its principles upon a definite and firm basis. In his introduction, the author of *Cosmos** says:—"Physical Geography depicts in broad outlines the even or irregular configuration of continents, the relations of superficial area, and the distribution of continental masses which exercise a powerful influence on the diversity of climate and the meteorological modifications of the atmosphere; this science defines the character of mountain chains, which, having been elevated at different epochs, constitute distinct systems, whether they run in parallel lines or intersect one another; determines the mean height of continents above the level of the sea, the position of the centre of gravity of their volume, and the relation of the highest summits of mountain chains to the mean elevation of their crests, or to their proximity with the sea shore. It depicts the eruptive

* *Cosmos*, introduction, p. 41, Bohn, London.

rocks as principles of movement, acting upon the sedimentary rocks by traversing, uplifting, and inclining them at various angles; it considers volcanoes either as isolated or ranged in single or double series, and extending their sphere of action to various distances, either by raising long and narrow lines of rocks, or by means of circles of commotion, which expand or diminish in diameter in the course of ages. This terrestrial portion of the science of the *Cosmos* describes the strife of the liquid element with the solid land; it indicates the features possessed in common by all great rivers in the upper and lower portion of their course, and their mode of bifurcation when their basins are enclosed, and shows us rivers breaking through the highest mountain chains, or following for a long time a course parallel to them, either at their base or at a considerable distance, where the elevation of the strata of the mountain system and the direction of their inclination correspond to the configuration of the table land. It is only the general results of comparative orography and hydrography that belong to the science whose true limits I am desirous of determining, and not the special enumeration of the greatest elevations of our globe, of active volcanoes, of rivers, and the number of their tributaries; these details falling rather within the domain of geography properly so called. We would here only consider phenomena in their mutual connection, and in their relations to different zones of our planet, and to its physical constitution generally. . . . . . The ultimate aim of Physical Geography is . . to recognise unity in the vast diversity of phenomena, and by the exercise of thought and the combination of observations, to discern the constancy of phenomena in the midst of apparent changes."

Comprehensive and precise, as is this admirable definition, yet it does not comprise various subjects that are ranged by later writers under the general title of Physical Geography, although it indicates quite a sufficient area for prolonged and careful and interesting study.

One of the most interesting volumes on Physical Geography that has been published in this country is that of our talented countrywoman, the late Mrs. Somerville. As she does not, however, favour us with a definition of the subject on which she writes, its extent must be gathered from the topics on which she dilates. Within the compass of her attractive work, she takes up, in addition to the subjects indicated by Humboldt, astronomy,

and meteorology, the geographical distribution of plants and animals, and the distribution, condition, and prospects of the human race; this last section including to some extent both ethnology and anthropology. Though these two last named subjects are certainly not mentioned by name, yet in the last chapter of the work "The Distribution of the Human Race" is treated in a manner which virtually covers both. In taking up in this chapter, progress of science, literature, the fine arts, music, poetry, &c., which may in some aspects be germane to anthropology, the gifted authoress has unquestionably trespassed beyond the widest reasonable limits that should be assigned to Physical Geography.

My late erudite friend, William Desborough Cooley, published, in 1876, an admirable volume entitled "Physical Geography; or, the Terraqueous Globe and its Phenomena." His definition of the subject is contained in the preface to this volume, which begins thus:—"Many, perhaps, on looking at this volume will be disposed to ask, 'What is Physical Geography?' To this question (which, under existing circumstances, is not inexcusable) I would reply that it is the department of science which embraces the course of physics reigning on the earth's surface, over land, sea and air, and of which—as it depends to some extent on the features of that surface—Geography is the function." This excellent and strictly scientific definition includes a wider range of subject than seems to be comprised in the definition by Humboldt which has been quoted, inasmuch as it includes astronomy and to some extent meteorology, both of which seem to be excluded from Physical Geography by the eminent German; and it agrees with that definition in excluding the geographical distribution of plants and animals and ethnology, all of which find a place in Mrs. Somerville's system.

In the two-fold division of the subject which we have adopted in the outset, it is obvious that under the first, namely, Physical Geography, must be included *Astronomical Geography*, which treats of the position of the earth in the solar system, its form, movements, etc.; *Mathematical Geography*, which teaches the scientific methods of ascertaining the exact form of the earth and of all portions of its surface, and their precise position in longitude and latitude, cartography, etc.; the geographical distribution of plants and animals; and Ethnology, so far as it relates to man merely as an organised being, in addition to the wide range of subjects specified in Humboldt's definition.

Dr. Arnold Guyot, an eminent American writer on Geography, and professor in the College of New Jersey, adopts a tripartite division of the subject. This he effects by making Astronomical and Mathematical Geography a separate division. Otherwise his distribution of the subject is very much the same as we have adopted. Allow me to quote a few sentences from this writer on Physical Geography which exhibit, in a very pleasing manner, the interesting course of study the subject involves :—

"*Physical Geography* seeks by careful comparison to discover the laws which regulate the structure and distribution of the land masses and oceans. It shows how the relief of the continents controls their drainage and shapes the vast river systems, so useful and so characteristic of each of them; how the very forms of the lands, together with their size and relative situation, modify the climate, the productions, and, therefore, the capacity of each country, for commerce and civilisations. It not only describes the great marine currents which circulate in the bosom of the ocean, but seeks to discover their causes, trace their connection, and the vast influence they exert upon climate, either by heating or cooling the superincumbent atmosphere. It is not enough for it to find that the temperature is highest in the equatorial regions of our globe, and gradually decreases towards the poles; it inquires into the cause of that fundamental law of the distribution of heat. But while this general law is well established, why is it that mountains which rise from the burning tropical plains of the Amazon and Ganges are capped with snow? that in January snow obstructs the streets in New York City, while in the same latitude the orange flourishes under a genial sun and mild temperature in Naples, and flowers and perpetual verdure grace the gardens in the islands of the Azores in the midst of the Atlantic? That on the east of the American Continent Labrador is but a frozen Peninsula, where no tree can grow, no agriculture is possible in the same latitude, where in Europe, on the other side of the Atlantic, the cities of Christiania, Stockholm, St. Petersburg, flourish in the midst of cultivated fields?

"Looking at the distribution of rain water, that other element of climate indispensable for all that has life on earth, why is it that it is so unequal, varying from a complete or almost total absence in the deserts, to an amount which would cover the ground with a layer of fifty feet of water? Why are the sunny regions of the tropics blessed with a quantity of rain water several times greater

than that which falls in our temperate regions, while the foggy regions toward the poles receive as many times less? Why are the rains periodical in the warm regions, and more and more equally distributed throughout the year as we recede from them toward the poles?

"To answer all such questions, suggested at every step to the reflecting observer of nature's phenomena, Physical Geography has to find out the laws which govern the distribution of heat and of the rain. It has to study the course of the winds, which are the carriers of warm and cold air from one place to another, and of the rains from the common reservoir of the continents. It thus shows that upon all these elements, properly combined and modified in their action by the forms, extent, and situation of the land masses and oceans, depend the distribution of life—vegetable and animal—on the surface of the globe, and the degree of usefulness to man of each portion of his domain."

Having thus dwelt, with some fulness, on the first great branch of our subject, let us turn to the second, namely, the "Geography of Man," or "Political Geography," which will not require to be treated at the same length as the former one, there being less diversity of opinion respecting its limits. It may be divided, conveniently, into Political Geography proper, and Ethnology. Political Geography includes a description of the various states into which the world is divided as political wholes—their boundaries, their resources, animal, vegetable, and mineral, their natural harbours, towns, political divisions, means of defence (or military Geography), system of government, trade and commerce, population, &c., &c., and thus forms a wide area of study, filled with important and attractive subjects, of the highest interest to thoughtful minds.

But an area of investigation no less wide, and no less interesting, is presented by Ethnology, which, according to a recent writer, "is a branch of the wider science of Anthropology. It is sometimes used as synonymous with *Ethnography*, but the latter, properly speaking, has a more limited scope, dealing mainly with the external features by which the various races of men are distinguished, while Ethnology takes note, both of the physical characteristics of the races of man, and also of their intellectual and moral peculiarities, their manners and customs, and the peculiar features of their languages, their political or social organisation, their origin, relationship, distribution, &c."

But, as a short definition such as this serves to convey to the mind a somewhat inadequate idea of the vast variety of subjects embraced within the proper province of Ethnology, a few particulars may be added, which may serve in some measure to fill up the canvas. Man, for example, is studied in those physical aspects which serve to mark the distinctions of race or tribe. Does the forehead recede like that of the Australian, or rise erect like that of the Caucasian? Is the skull long like that of the Scandinavian, or bullet-shaped like that of the German? Is the hair black like that of the Celt, or fair like that of the Saxon? Are the eyes almond-shaped like those of the Chinese? Are the soles of the feet flat like those of the Russians? Does he tatoo the body, pierce the septum of the nose, or enlarge the lobes of the ears? Such are some of the questions that engage the attention in reference to the physical conformation of man, and through the observation of which much may be learned of the position the individual or tribe holds in the great community of the human race. The relics of man in former ages come in for much attention, such as the stone weapons and implements used in prehistoric times, which may be compared with similar weapons in use at the present day among peoples of low civilisation, and those cromlechs, tolmens, stone circles, which we associate with the name of Druids, many of which are found in our own country, in France, India, and elsewhere.

The remains of cranoges or lake-dwellings, found notably in Scotland, Ireland, and in Switzerland, may be compared with the existing dwellings of some of the Malay peoples of the Indian Archipelago, erected in like manner on platforms fixed on piles, projecting out into the water, on the margins of rivers and lagoons, and we may endeavour thereby to realise in some sort the state of civilisation and social comfort in which our ancestors lived in the primeval times, when such erections formed their ordinary places of abode.

The bee-hive dwellings in the Island of Lewis may be compared with similarly-shaped houses, built of snow, in the Arctic regions, and the dome-shaped wigwams of Southern Africa; and we may endeavour to trace the steps by which, starting from such simple structures, man could attain to the advanced condition in which he must have been when he hewed out of the living rock the magnificent Temples of Ellora in India, built the Pyramids of Egypt, and the Palaces of Nineveh. In this manner we may proceed step by step to one branch of this fascinating study

after another—to language, which is often a more permanent characteristic than even physical conformation—to food, clothing, boats, social relations, religious beliefs, and religious ceremonies, all of which, one way or another, mark in a distinctive manner the place occupied in the human race by the people among which they prevail.

I must now draw this address to a close. It has been extended much beyond the limits originally contemplated. However, I shall not regret this undesired extension, if thereby I have succeeded in conveying to the Society a general impression, however imperfect, of the wide field of study and observation, which lies before those who would worthily cultivate the attractive sciences of Geography and Ethnology.

V.—*On the use of Litmus, Rosolic Acid, Methyl Orange, Phenacetolin, and Phenolphthaleïn as Indicators.* Part II. By ROBERT T. THOMSON.

[Read before the Chemical Section, 10th December, 1883.]

THE first part of this paper was confined exclusively to the use of these indicators in the analysis of some of the more important compounds of potassium, sodium, and ammonium, and to the determination of free acids by hydrate of sodium. Since then I have devoted some attention to their behaviour with a few compounds of calcium, barium, and magnesium. In this portion of the subject I have been forestalled to some extent by other chemists, who have published results which will be referred to as they present themselves for consideration in the following paper:—

I.—Application of the indicators to the determination of lime existing as hydrate, with a small proportion of carbonate.

For each experiment 200 c.c. of lime water were employed, and to this was added ·0265 gram. of carbonate of sodium, which precipitated an equivalent proportion of carbonate of calcium. This was done in a *cold* solution. The total lime (CaO) present was ·2724, and that existing as hydrate ·014 gram. The estimation was accomplished by half-normal hydrochloric acid, and from the result was deducted the number of c.c. required to neutralize the hydrate of sodium produced by the action of the carbonate of sodium added.

Litmus.—When this indicator was employed the test acid was added in the cold (this being the course pursued in each case) until the colour became purple. The solution was then boiled, and the addition of acid continued until the blue colour gave place to red, the end-reaction being very distinct. 19·4 c.c. were consumed in one experiment and 19·5 in another, results which closely agree

with the total amount of lime present. It is needless to give the results more minutely at this stage, as they will be arranged in a short table at the end of this section along with those obtained with the other indicators.

Rosolic Acid.—The remarks made concerning litmus apply with equal weight to rosolic acid, except in the matter of colour, the latter indicator changing from deep pink to yellow. 19·4 c.c. of the standard acid were required in each case.

Methyl Orange.—With this indicator practically the whole of the lime was determined in the cold, no boiling being necessary, owing to the fact that the liberated carbonic acid has no effect on the colour. The results were precisely the same as those obtained with rosolic acid.

Phenacetolin.—The value of phenacetolin for the purpose under examination has been accurately estimated by Prof. Lunge, and it is therefore only for completeness' sake that it is here dealt with. The method is similar to that fully described in the first part of this paper for the estimation of hydrate in presence of a little carbonate of sodium. The hydrate of calcium is first determined by adding the standard acid until the scarcely perceptible yellow colour is transformed to a distinct permanent pink, and then the proportion of carbonate of calcium is obtained by further addition of acid until the pink gives place to a deep yellow colour. For the two tests 18·4 and 18·3 c.c. were required respectively to neutralize the hydrate, while an additional 1·1 c.c. was necessary to decompose the carbonate of calcium.

It may not be out of place to remark here that my experience with phenacetolin leads me to the conclusion that it requires more skill in manipulation, when used for the determination of hydrate of potassium, sodium, or calcium, than is altogether desirable. The operator has not to deal with a sharp and unmistakable end-reaction, but is left to a certain extent in a state of indecision as to the exact point at which the pink colour, due to the action of the carbonate after neutralization of the hydrate, shows itself. With experience, however, I have no doubt that good and concordant results are obtainable. Of course these remarks do not apply to the determination of soda or lime in the state of carbonate.

Phenolphthaleïn.—As was to be expected, this indicator, under favourable circumstances, behaved in the same way as in the parallel determination of the respective proportions of hydrate and carbonate of sodium. The test acid was added as carefully as

possible, especially after nearly all the hydrate of calcium was neutralized, to prevent loss of carbonic acid; and when 18·9 in one experiment, and 18·85 c.c. in another, had been added, the red colour which had been diminishing in intensity was entirely discharged. At the same time the carbonate of calcium had passed completely into solution, a faint turbidity which remained being no doubt due to the phenolphthaleïn. The results show that the whole of the lime existing as hydrate, and half of that existing as carbonate, had been estimated, thus proving that bicarbonate of calcium is neutral to phenolphthaleïn, just as the bicarbonate of potassium and sodium are. The solution was now boiled for a considerable time, but the red colour did not reappear, although normal carbonate of calcium was precipitated, the bicarbonate being decomposed, and carbonic acid expelled. On adding excess of acid, boiling, and titrating back with caustic alkali, the whole of the lime was obtained. To verify these results, and account for the apparently anomalous behaviour of carbonate of calcium towards phenolphthaleïn, ·2 gram. of the former compound, freshly precipitated from a cold solution (hydrate being absent), was treated with the half normal acid. After 4·1 c.c. had been added, all the carbonate of calcium was found to be dissolved, and the red colour had disappeared. The result is equal to ·1025 gram. of carbonate of calcium, or almost exactly half the quantity used, and this agrees with the results quoted above. On boiling, the calcium carbonate was precipitated as a hard crust on the beaker, but the colour did not return, and it now remains to inquire why this is so. Another test showed that although carbonate of calcium, recently precipitated from a cold solution, gives an alkaline reaction with phenolphthaleïn; if it is boiled, no colouration is produced. At the same time the carbonate of calcium is converted from a light flocculent condition into a dense granular form, and it seems that only in the former state can the indicator penetrate into it and develop the red colour. A portion of this dense form of the compound was collected, dried, and ground finely in the agate mortar; but even then only a faint red tint was produced, which disappeared on simple boiling, or on addition of a mere trace of acid. From these facts the conclusion may be safely drawn that hydrate can be determined in presence of carbonate of calcium by simply adding standard hydrochloric acid to a boiling solution till the red colour is gone. The lime existing as hydrate will thus be estimated, while that existing as carbonate will be left untouched.

To apply this process, a sample of slaked lime which had become carbonated to a considerable extent, and in which the total lime and carbonic acid were estimated in the ordinary way, was treated as above described. To 1 gram. of the sample a quantity of boiling water was added, the mixture boiled for a few seconds and then titrated with half-normal acid, all the hydrate of calcium being brought into solution by agitating well after each addition. In two experiments, 40·4 and 40·5 c.c. were consumed respectively, which give as an average ·5663 gram. of lime (CaO) existing as hydrate, while the amount obtained by estimating the total lime by the ordinary gravimetric method, and subtracting that existing as carbonate, was ·5660 gram. The carbonate of calcium was then determined by adding excess of standard acid, boiling, and titrating back with caustic soda. For this part of the process, 8·1 and 8·15 c.c. respectively of the half-normal acid were consumed, giving as an average ·1137 gram. of lime existing as carbonate of calcium, while that calculated from the carbonic acid estimation was ·1130 gram. Taking into consideration these results, and also those quoted above, it is not too much to say that the complete neutrality of carbonate of calcium to phenolphthaleïn under the circumstances described may be depended upon without the least hesitation.

TABLE I.

Showing results obtained by each indicator when used in the determination of lime as hydrate with a small proportion of carbonate of calcium.

Lime, existing as hydrate, employed, ...	·2584
Do., do. carbonate, do., ...	·0140
Total lime employed, ...	·2724

Name of Indicator.	Gram. of total CaO found.		Gram. of CaO as hydrate found.		Gram. of CaO as carbonate found.	
Litmus, . . .	·2716	·2730	...		...	
Rosolic acid, . .	·2716	·2716	...		...	
Methyl orange, .	·2716	·2716	...		...	
Phenacetolin, .	·2730	·2716	·2562	·2576	·0154	·0154
Phenolphthaleïn, .	·2716	·2716	·2590	·2576	·0140	·0154

TABLE II.

Showing proportions of lime, existing as hydrate and carbonate respectively, in a sample of slaked lime (1) by alkalimetric method, using phenolphthaleïn as indicator, and (2) by the ordinary gravimetric method for determination of lime and carbonic acid.

By Alkalimetric Method.		By Gravimetric Determination of Lime and Carbonic Acid.	
Gram. of CaO as hydrate found.	Gram. of CaO as carbonate found.	Gram. of CaO as hydrate found.	Gram. of CaO as carbonate found.
·5656	·1134	·5660	·1130
·5670	·1141	·5665	·1128

II.—Determination of lime existing as carbonate.

As the principal points in connection with this portion of the subject have already been alluded to, it will only be necessary to make one or two supplementary remarks. Litmus, rosolic acid, phenacetolin, and methyl orange can all be used with advantage for this estimation, especially when the carbonate of calcium is in the light flocculent condition. The first three of these indicators are not by any means so delicate when that compound is in a more dense form. The behaviour of phenolphthaleïn has been already fully discussed.

III.—Determination of hydrate and carbonate of barium.

All that has been noted with regard to *litmus*, *rosolic acid*, and *methyl orange* for the determination of lime applies with equal force to that of baryta.

Phenacetolin can be employed for the estimation of the respective proportions of baryta existing as hydrate and carbonate.

Phenolphthaleïn acts in the same way as it does with the calcium compounds, and may be used to find the quantity of hydrate of barium in presence of the carbonate, the latter remaining neutral. It is noteworthy, however, that carbonate of barium, even when

freshly precipitated from a cold solution, does not develop a red colour with phenolphthaleïn but remains neutral. If a little colour is produced it is permanently dispelled by a mere trace of acid or by simple boiling.

IV.—Determination of hydrate and carbonate of magnesium.

The total magnesia existing as hydrate and carbonate can be determined by adding excess standard sulphuric acid, boiling to dissolve perfectly and expel carbonate acid, and then titrating back with alkali. For this purpose any of the indicators may be employed. Magnesia in solution, as bicarbonate, can be determined directly by standard acid, in the cold with methyl orange, or in the boiling solution with any of the other indicators.

The estimation of hydrate in presence of carbonate of magnesium, using phenacetolin or phenolphthaleïn as indicator, is almost impossible, as the hydrate is so insoluble in water, and the limited supply of acid which requires to be added attacks it so slowly that the results are eminently unsatisfactory.

Before passing on to other compounds, special attention ought to be drawn to the method recently proposed by Hehner (*Analyst*, vol. VIII., page 77), for the "Estimation of hardness without soap solution." By this process, which should certainly supersede the less accurate soap test for the hardness of waters, the hardness due to the carbonates of calcium and magnesium is first determined directly by standard acid in one portion of the sample. The titration must be done in a hot solution if phenacetolin, cochineal, or rosolic acid is employed as indicator, or in the cold if methyl orange is used. The author of the process recommends phenacetolin as the most delicate, and this is undoubtedly the case. Having thus determined the temporary hardness, to another portion of the sample a measured quantity of standard carbonate of sodium, which must be in considerable excess, is added, and the mixture boiled till all the calcium and magnesium salts are converted into carbonate. The precipitate produced is filtered off, and the excess of carbonate of sodium determined in the filtrate by standard acid. The difference between this result and the total quantity of carbonate of sodium added is calculated to carbonate of calcium, the answer being, when brought to grains per gallon, the degrees of hardness due to salts of calcium and magnesium other than carbonate. It

would be out of place to add anything to the convincing experiments published by Hehner, further than to state that, as the result of experiments on samples of water, I have found that the degrees of hardness obtained by this simple process agree very closely with those secured by calculation from the proportions of the various compounds of calcium and magnesium, determined by the ordinary gravimetric methods. One point, seldom or never referred to, is the presence of carbonate of sodium, which is not unfrequently met with in water. When this compound is present it is obvious that the determination of temporary hardness will be high, and that, in estimating the permanent hardness, the amount of carbonate of sodium obtained will be greater than the quantity added. This increase, calculated to carbonate of calcium, and deducted from the result at first recorded as temporary hardness, will give the true temporary hardness. And this will also represent the total hardness, as a water containing carbonate of sodium cannot contain salts of calcium and magnesium other than carbonate.

V.—Chloride, nitrate, and sulphate of calcium, barium, and magnesium.

These salts are neutral to all the indicators, and only in the case of methyl orange somewhat more standard acid is required to produce the full change in colour, when the end-reaction is reached, than is necessary in solutions free from these salts. This is also true, as I had occasion to point out before, with regard to the neutral salts of sodium, potassium, and ammonia.

It has been established above that carbonate of calcium, when precipitated from a solution and boiled, is neutral to phenolphthaleïn. This is so decidedly the case that the amount of calcium can be determined in any neutral compound of that metal by titration with carbonate of sodium. The method of procedure is to add phenolphthaleïn, then neutralize with hydrate of sodium if acid, and finally add standard carbonate of sodium till the red colour at first developed is no longer discharged on boiling for a few minutes, but remains permanent. Two experiments made respectively with chloride and nitrate of calcium (each solution containing ·096 gram. of calcium) consumed 9·6 and 9·65 c.c. of half normal carbonate of sodium, the results being almost exactly the same as the amount of lime really present.

Similar results were obtained with barium chloride; but with magnesium salts a red coloration is produced immediately on addition of a little carbonate of sodium, and is not dispelled even by prolonged boiling. The above process, therefore, cannot be used for the estimation of calcium in presence of magnesium salts, as these seem to be decomposed simultaneously with the calcium compounds, and produce a coloration at once.

VI.—Sulphites of calcium and magnesium.

For each experiment ·525 grain of normal sulphite of calcium was employed, and this was prepared by mixing a quantity of solution of sulphurous acid containing ·28 gram. of SO_2, with hydrate of calcium solution containing ·245 gram. CaO.

Litmus.—With this indicator the change in colour was very gradual, so that anything like a desirable degree of certainty could not be attained to. As about 8·5 c.c. of the half normal hydrochloric acid were consumed, it is evident that the bisulphite of calcium may be roughly regarded as the salt neutral to litmus, while the normal sulphite is strongly alkaline.

Rosolic acid.—Unlike litmus, gives a sharp and well defined end-reaction, the result of two experiments being that only a mere trace of acid was required to discharge the pink colour in a cold solution, while in a boiling solution ·4 and ·5 c.c. were respectively consumed. These results clearly show that normal sulphite of calcium is practically neutral to rosolic acid in a cold solution, although it shows a considerable alkaline reaction when boiling.

Methyl orange.—Agrees with rosolic acid in giving a delicate end reaction, but here all likeness ceases. For the two tests 8·7 and 8·75 c.c. of half-normal acid were respectively required, which give as an average ·1221 gram. of lime, or almost exactly half the amount really present. The bisulphite of calcium is thus neutral to methyl orange.

Phenacetolin.—Acts in every respect like litmus, giving an exceedingly indefinite end-reaction, to bring out which about 8·5 c.c. of the standard acid was consumed.

Phenolphthaleïn.—The normal sulphite of calcium is neutral to this indicator, both in a cold and boiling solution, probably being so in the latter, because the sulphite of calcium is all, or nearly all, precipitated, and cannot attack the phenolphthaleïn.

TABLE III.

Showing results obtained in the titration of calcium sulphite with half-normal hydrochloric acid.

Amount of $CaSO_3$ employed for each test, ... ·545 gram.
Equal CoO, ,, ,, ... ·245 do.

Name of Indicator.	C.C. Half-normal Acid consumed.	Gram. CaO obtained.
Litmus, ...	8·5	·1190
Rosolic acid (cold), . .	—	trace
Do. (boiling), . .	·4—·5	·0056—·0070
Methyl orange, . . .	8·7—8·75	·1218—·1225
Phenacetolin, . . .	8·5	·1190
Phenolphthaleïn (cold), . .	—	trace
Do. (boiling), .	—	—

As regards magnesium sulphite, it is only necessary to remark, that it acts in exactly the same way towards these indicators as calcium sulphite. A description of the experiments made would be merely a repetition of what has been already related concerning the latter compound.

Leaving out of sight the results obtained with litmus and phenacetolin (these indicators being absolutely useless for all purposes connected with the accurate testing of sulphites), and looking more closely at those brought out when rosolic acid, methyl orange, and phenolphthaleïn were employed, it is plainly evident that a method might be constructed for the determination of the proportion of sulphurous acid in a solution of that compound, or of bisulphite of lime. Such a process would obviously be based on the difference of indication shown by methyl orange, on the one hand, and rosolic acid or phenolphthaleïn, on the other, the bisulphite of calcium ($CaH_2(SO_3)_2$), being neutral to the first-mentioned indicator, while the remaining two indicate the normal calcium sulphite ($CaSO_3$) as the neutral salt. The analogous behaviour of these three indicators with the sulphites of sodium and potassium was pointed out in the first part of this paper. To perform the titration, measure out a portion of the sample (from

20 to 50 c.c. will be convenient quantities), add methyl orange, then solution of caustic soda, if acid, or hydrochloric acid, if alkaline, from a burette, till the neutral point is reached. Now add rosolic acid or phenolphthaleïn, and then normal or half-normal hydrate of sodium, till the characteristic pink, or red colour, is just apparent. Multiply the number of c.c. consumed during the second stage of this process by ·064 if normal alkali is used, and the answer will be the number of grammes of SO_2 in the quantity of sample operated upon.

The following were results obtained in testing equal volumes of a sample of bisulphite of lime, both by this and the volumetric iodine method.

TABLE IV.

Showing results obtained in testing bisulphite of lime by the alkalimetric and volumetric iodine methods, respectively.

Alkalimetric Method.			Iodine Method.
Name of Indicator.	c.c. of $\frac{N}{2}$ NaHO consumed.	Gram. of SO_2 found.	Gram. of SO_2 found.
Rosolic Acid, .	14·4	·4608	·4590
Phenolphthaleïn,	14·4	·4608	·4570

It is obvious, from the nature of the process, that sulphuric or hydrochloric acid cannot have any effect on the accuracy of the above process, as they give rise to salts neutral to rosolic acid, phenolphthaleïn, and methyl orange, during the first addition of caustic soda. The presence of phosphoric acid, however, would be very injurious, as it would be partly counted as sulphurous acid. The only other substance likely to vitiate the results so far as to make them useless is carbonic acid, which, as has been abundantly proved, has a very great effect on rosolic acid and phenolphthaleïn, but more especially on the latter. The solution in this case cannot be boiled to expel carbonic acid, as it can in the similar determination of phosphoric acid in phosphate of soda, after bringing it to the neutral point with methyl orange as indicator. It is therefore necessary to use a standard soda solution free from carbonate of sodium. To obtain this make up a solution of caustic soda, and

determine in it the sulphate and carbonate of sodium, the former by precipitation as barium sulphate and the latter by titration with acid, using phenolphthaleïn or phenacetolin as indicator. Now knowing the proportion of these impurities, it is only necessary to take a measured quantity of the solution of hydrate of sodium, add a quantity of chloride of barium equivalent to the carbonate and sulphate of sodium present, allow the precipitate to settle, and syphon off the clear liquor, which is then only to be tested and reduced to the required standard.

VII.—Borates of calcium, magnesium, potassium, and ammonium.

In the former portion of this paper it was shown that the whole of the soda could be estimated in borax by standard acid, for which purpose methyl orange alone was perfect, or, indeed, admissable. To ascertain if the borates of calcium would yield corresponding results, 2 gram. of pure boric acid were dissolved in water, and a quantity of solution of calcium hydrate containing ·1370 gram. of lime added. The solution of borate of calcium, containing excess of boric acid, thus obtained was then titrated with half-normal acid, of which 9·8 c.c. were consumed in two experiments, giving ·1372 gram. of lime in each case. The end-reactions were extremely delicate, and left nothing to be desired.

Similar tests were made with the borates of magnesium, potassium, and ammonium, and in each compound the whole of the base was estimated with as great accuracy as in the borates of sodium and calcium.

It will now be evident that any of these borates may be determined by standard acid in samples of boric acid. Even the very smallest proportion of a borate can thus be detected, as a specimen of pure boric acid did not show the least acid reaction with methyl orange, the pink colour being immediately developed on addition of one drop of normal acid, and the yellow colour brought back by a drop of normal alkali. Methyl orange will also be found useful in the analysis of commercial borates of lime and boracite; but in titrating these it may be found necessary, in order to get them perfectly into solution, to add excess of the standard acid, then heat till dissolved, allow to cool, and titrate back with standard hydrate or carbonate of sodium.

VIII.—Phosphates of calcium.

The tricalcium orthophosphate (Ca_32PO_4) being insoluble in water has no effect on any of the indicators, while the monocalcium compound (CaH_42PO_4) is neutral (as will be demonstrated immediately) to methyl orange, but is strongly acid to litmus, rosolic acid, phenacetolin, and phenolphthaleïn. It would seem feasible, if a suitable indicator could be obtained (and this we have in phenolphthaleïn), to determine phosphoric acid in a solution containing the monocalcium phosphate with excess of a neutral calcium salt present, by adding standard hydrate of sodium to the boiling solution till all the tribasic phosphate of calcium was precipitated. In any attempts I have met with to accomplish this object, the separation of the lime is insisted on as necessary on the ground that ordinary superphosphates contain sulphate of calcium, which would be developed by the carbonate of sodium employed for titration, and give high results. Now, this difficulty can be overcome by employing hydrate of sodium free from carbonate; but, unfortunately, another and insuperable difficulty renders such a process useless. This is shown by the following experiments. A solution was prepared by dissolving a weighed quantity of pure tricalcium phosphate in hydrochloric acid, diluting and adding caustic soda till the solution, which had been coloured pink by methyl orange, was rendered distinctly yellow. The mixture was then made up to a certain volume, so that 50 c.c., the quantity used for each test, contained phosphoric acid and calcium exactly equivalent to ·62 gram. of Ca_32PO_4. After addition of phenolphthaleïn, half-normal caustic soda (1 c.c. of which will, under the circumstances, be equal to ·03875 gram. of Ca_32PO_4) was added, the first two drops producing a faint but distinct precipitate, until after boiling well a permanent red colour was produced, showing that all the phosphate of calcium was precipitated. Other tests were made with the same quantity of phosphate solution to which had been added various proportions of pure calcium chloride. The following were the results:—

·6200 grams. $Ca_3\ 2PO_4$ really present.					
·6225	do.	obtained without addition of $CaCl_2$.			
·6400	do.	do.	after adding	·055 gram.	$CaCl_2$.
·6614	do.	do.	do.	·111	do.
·6750	do.	do.	do.	·555	do.

These results show that a basic phosphate must be to some extent

produced, the amount being greater when the proportion of neutral calcium salt present is greater, although even in the experiment made with the smallest quantity of calcium chloride, the most part of that compound remained in solution after the titration was finished. By the first of these tests—that made with the pure phosphate solution without addition of calcium chloride—it is proved that the monocalcium phosphate (CaH_4PO_4) is neutral to methyl orange, because if it were not so, the result would have been either high or low, whereas it is at least within the limits of error. In corroboration of this, it has been already noted that the neutral point obtained by the use of methyl orange comes very close to that shown by the ordinary method of adding alkali till a faint precipitate appears. As would be expected, the methyl orange indicates neutrality just before any precipitate is produced, and to verify the fact several additional tests were made. It may be worthy of a passing note to mention that, when the titration described above is accomplished in the cold, much less of the alkali is consumed, the whole of the phosphoric acid is precipitated, but a considerable portion of the lime remains in solution. On boiling, the colour is dispelled and the same results as those quoted above are obtained.

Having now discovered sufficiently grave reasons to discard the process described above, it will be well to examine the "New Method for the volumetric determination of Phosphoric Acid in the Superphosphates," proposed by A. Mollenda (*Chem. News*, vol. xlvii., page 231). This process consists in adding an alkali to the solution in which the phosphoric acid is to be determined, until a faint precipitate appears, then precipitating the lime in a boiling solution with oxalate of sodium, filtering off the oxalate of calcium, and titrating the filtrate, which now contains the monosodium phosphate (NaH_2PO_4), with hydrate or carbonate of sodium, using litmus, phenacetolin, or phenolphthaleïn as indicator. The author of the article referred to prefers the latter indicator, and in that case caustic soda or potash must be used. In the first part of this paper I proposed a similar method for the determination of phosphoric acid in phosphate of sodium, which depended on the difference of indication shown by methyl orange and phenolphthaleïn, but in this case the former indicator cannot be employed after precipitation of lime, as oxalate of sodium acts like an alkali toward it. It may be used in the neutralization before precipitating the lime, instead of depending on the less exact

appearance of a faint precipitate. In two determinations, made with ·62 grams. of pure tricalcium phosphate, by Mollenda's method thus modified, 7·9 and 7·95 c.c. of half-normal caustic soda were consumed respectively. As the equivalent of 1 c.c. in Ca_32PO_4 is ·0775 gram., the amounts thus brought out gave as an average ·6142 gram. These quantities are decidedly too low, but the difference may be accounted for partly through a little of the phosphate being precipitated with the oxalate of calcium, but must be chiefly assigned to the slight alkalinity of disodium phosphate (Na_2HPO_4), produced by the action of the sodium hydrate. An allowance, based on tests made with pure disodium phosphate, of 100th part of the whole phosphate present will eliminate the error thus caused. With regard to the use of litmus or phenacetolin in place of phenolphthaleïn, I can only repeat what was noted formerly, that not only are the neutral points indicated by the two former entirely different from the latter, but the end-reactions are so uncertain as to render them useless where anything approaching to trustworthy results are required.

A few experiments were next devoted to the estimation of phosphate of calcium in presence of iron. The solution employed contained ·62 gram. of phosphate of calcium and perchloride of iron equivalent to ·006 gram. of ferric oxide. Carrying out Mollenda's process *unmodified* (that is, utilizing the production of the faint precipitate to indicate the neutral point), three experiments gave ·7002 and one test gave ·7020 gram. of Ca_3PO_4. These results are so extremely high that they would give a difference of 3 or 4 per cent. in an ordinary superphosphate of average strength. The results were the same when the preliminary neutralization was done in a boiling solution. More alkali was required to effect the preliminary neutralization when methyl orange was employed, and at the same time a considerable precipitate was produced. This precipitate was collected, and on applying the necessary tests proved to be pure ferric phosphate. It weighed 7 milligrams, and thus contained about two-thirds of the total iron present. The filtrate was then treated with sodium oxalate, and titrated with half-normal caustic soda, and on adding the weight of the ferric phosphate precipitate, the total amount agreed with those obtained from pure tricalcium phosphate.

A small quantity of aluminium was found to have the same effect as iron, and it is evident that these two metals must be removed, as otherwise, even if they remain in solution, correct

results cannot be expected. These results show that, in constructing a method of chemical analysis, every possible, and even what may with some show of reason be considered impossible, source of error must be taken into account, and the subject carefully worked out.

The accuracy of the process does not seem to be affected by neutral magnesium salts, but it cannot be applied directly to superphosphates containing ammonium salts, as these injure the delicacy of the phenolphthaleïn. On the whole, no more can be said in favour of this method than that, under suitable conditions, it will give a near approximation to the truth.

IX.—Behaviour of the indicators with carbolic acid, &c.

Having had occasion to test directly the alkalinity of a certain ammonia liquor, among other indicators I used rosolic acid, and found the pink colour at first developed was quickly destroyed, and could not be brought back with caustic soda. This led to testing the action of carbolic acid, with the result that that body was found to be neutral to litmus, rosolic acid, methyl orange, and phenacetolin, and that none of them was destroyed even after prolonged contact. Two grams. of pure phenol dissolved in water and phenolphthaleïn added, required 1·2 c.c. of half-normal alkali to produce a faint red coloration, but a considerable additional quantity was required to bring out the full intensity of colour. The result shows that 100 grams. of phenol require ·63 gram. of soda (Na_2O) to make it neutral to phenolphthaleïn, but the end-reaction is extremely indistinct.

On another occasion I wished to determine the soda in a solution of sodium sulphide prepared by passing sulphuretted hydrogen through caustic soda, and found that, on adding acid in excess, the methyl orange employed seemed to have been destroyed, and gave no pink colour. There was a little sulphur precipitated, and thinking that it might have some reducing action, I made a test with a mixture of sulphite and thiosulphate of sodium, but the precipitated sulphur did not hinder the pink colour from appearing, and remaining permanent. I have not yet had time to experiment further in the direction of solving these problems connected with rosolic acid and methyl orange.

In the following table is given an epitome of the results obtained

in the first and second parts of this paper, including a few results recorded by other chemists:—

Table of the behaviour of litmus, rosolic acid, methyl orange, phenacetolin, and phenolphthaleïn as indicators in the determination of alkali by standard acids, and of acids by standard alkali. Constructed by Robert T. Thomson, City Analysts' Laboratory, 138 Bath Street, Glasgow.

In the following table are given the parts, by weight, of base or acid which can be estimated by standard acid or alkali in the various compounds, when 100 parts of the base or acid are present. The figures relating to the fats and fatty and resin acids are given on the authority of Hehner and Allen. When the end-reaction is noted as "uncertain," it must be understood that the indicator is practically useless, unless specified otherwise in a note.

Compounds Titrated.	Condition of Solution.	PER CENT. OF BASE ESTIMATED WITH				
		Litmus.	Rosolic Acid.	Methyl Orange.	Phen-acetolin.	Phenolphthaleïn.
KHO, NaHO, $Ca(HO)_2$, $Ba(HO)_2$,	Cold Boiling End-react'n	100 100 Delicate	100 100 Delicate	100 100 Delicate	100 100 Delicate	100 100 Delicate
NH_4HO,	Cold End-react'n	100 Delicate	100 Delicate	100 Delicate	100 Delicate	97 Uncertain
K_2CO_3, Na_2CO_3,	Cold Boiling End-react'n	... 100 Delicate	... 100 Delicate	100 ... Delicate	... 100 Delicate	50 (1) 100 Unct'n, cold Delicate, hot
$(NH_4)_2CO_3$,	Cold End-react'n	... ...	... ...	100 Delicate	... (2) ...	Cannot be used at all.
$CaCO_3$, $BaCO_3$,	Cold Boiling End-react'n	... 100 Delicate	... 100 Delicate	100 ... Delicate	... 100 Delicate	0 (3) 0 ...

(1) The end-reaction in the cold is distinct when only small quantities (say not more than ·1 gram.) of the carbonate are present.

(2) Litmus, rosolic acid, or phenacetolin can be used if excess of acid is added, the solution boiled, and titrated back with alkali.

(3) 50 per cent. is estimated if $CaCO_3$ (but not $BaCO_3$) is freshly precipitated, but not after boiling.

Compounds Titrated.	Condition of Solution.	PER CENT. OF BASE ESTIMATED WITH				
		Litmus.	Rosolic Acid.	Methyl Orange.	Phen-acetolin.	Phenolphthalein.
$NaHCO_3$, $KHCO_3$, $CaH_2(CO_3)_2$,	Cold Boiling End-react'n	... 100 Delicate	... 100 Delicate	100 ... Delicate	... 100 Delicate	0 100 (4) Delicate
MgO, $MgCO_3$,	Cold Boiling End-react'n	... 100 Delicate	... 100 Delicate	100 ... Delicate	... 100 Delicate	... 100 Delicate
Na_2SO_3, K_2SO_3,	Cold Boiling End-react'n	About 50 ... Uncertain	·4 10·2 Delicate	50 ... Delicate	About 50 ... Uncertain	·4 8·0 Delicate
$(NH_4)_2SO_3$,	Cold End-react'n	About 50 Uncertain	·4 Delicate	50 Delicate	About 50 Uncertain	Cannot be used.
$CaSO_3$, $MgSO_3$,	Cold End-react'n	About 50 Uncertain	·4 Delicate	50 Delicate	About 50 Uncertain	·4 Delicate
Na_2S, K_2S,	Cold Boiling End-react'n	... 100 Delicate	... 100 Delicate	100 ... Delicate	... 100 Delicate	50 100 { Unct'n, cold Delicate, hot
$(NH_4)_2S$,	Cold End-react'n	... ...	... ...	100 Delicate	... (5) ...	Cannot be used
Na_2HPO_4, K_2HPO_4,	Cold Boiling End-react'n	About 50 do. Uncertain	About 50 do. Uncertain	50 ... Delicate	About 50 do. Uncertain	1·0 5·5 Delicate
$(NH_4)_2HPO_4$,	Cold End-react'n	About 50 Uncertain	About 50 Uncertain	50 Delicate	About 50 Uncertain	Cannot be used
NaH_2PO_4, KH_2PO_4, $CaH_4(PO_4)_2$,	... End-react'n	Acid ...	Acid ...	Neutral Delicate	Acid ...	Acid ...
Na_2HAsO_4, K_2HAsO_4,	Cold Boiling End-react'n	About 50 do. Uncertain	About 50 do. Uncertain	50 ... Delicate	About 50 do. Uncertain	1·0 6·5 Delicate

(4) This only applies to the sodium and potassium salts.
(5) See note 2.

Compounds Titrated.	Condition of Solution.	PER CENT. OF BASE ESTIMATED WITH				
		Litmus.	Rosolic Acid.	Methyl Orange.	Phen-acetolin.	Phenolphthalein.
NaH_2AsO_4, KH_2AsO_4,	... End-react'n	Acid ...	Acid ...	Neutral Delicate	Acid ...	Acid ...
$NaAsO_2$, $KAsO_2$,	Cold Boiling End-react'n	100 do. Delicate	100 do. Delicate	100 do. Delicate	100. do. Delicate	90·7 89·7 Somewhat indistinct
Silicates of Na and K,	Cold Boiling End-react'n	100 100 Delicate	... 100 Delicate	100 ... Delicate	100 100 Delicate	88 90 Uncertain
Borates of Na, K, NH_4, Ca, and Mg,	Cold Boiling End-react'n	100 100 Uncertain	100 100 Uncertain	100 ... Delicate	100 100 Uncertain	46 (6) 67 Uncertain
Al_2O_3, (freshly precipitated),	Cold Boiling End-react'n	... 1 Delicate	... 1 Delicate	About 100 ... Unct'n (7)	0 0 Delicate	0 0 Delicate

Compounds Titrated.	Condition of Solution.	PER CENT. OF ACID ESTIMATED WITH				
		Litmus.	Rosolic Acid.	Methyl Orange.	Phen-acetolin.	Phenolphthalein.
H_2SO_4, HCl, HNO_3,	Cold End-react'n	100 Delicate	100 Delicate	100 Delicate	100 Delicate	100 Delicate
$H_2C_2O_4$,	Cold End-react'n	100 Delicate	100 Delicate	90 Uncertain	100 Uncertain	100 Delicate
$HC_2H_3O_2$,	Cold End-react'n	99·8 (8) Uncertain	100 Uncertain	12 Uncertain	96 Uncertain	100 Delicate
$H_2C_4H_4O_6$,	Cold End-react'n	100 Somewhat indistinct	100 Somewhat indistinct	80 Uncertain	99 Uncertain	100 Delicate

(6) This does not apply to ammonium borate.
(7) End-reaction is tolerably distinct when only small quantities of Al_2O_3 are present.
(8) The standard NaHO used was standardized with normal H_2SO_4.

Compounds Titrated.	Condition of Solution.	PER CENT. OF ACID ESTIMATED WITH				
		Litmus.	Rosolic Acid.	Methyl Orange.	Phen-acetolin.	Phenolphthaleïn.
$H_3C_6H_5O_7$,	Cold End-react'n	98·5 (8) Uncertain	99 Uncertain	45 Uncertain	86 Uncertain	100 Delicate
Phenol.	Cold End-react'n	Neutral Delicate	Neutral Delicate	Neutral Delicate	Neutral Delicate	100 gms. Phen. consumes ·63 gms. Na_2O Uncertain
Fatty and Resin Acids and Neutral Fats.	The following substances can be determined by standard alcoholic potash, phenolphthaleïn as indicator. One c.c. normal caustic potash (1 c.c. = ·056 grm. KHO) is equal to— ·088 gram. butyric acid. ·1007 gram. tributyrin. ·282 do. oleic. ·2947 do. triolein. ·256 do. palmitic. ·2687 do. tripalmitin. ·284 do. stearic. ·2967 do. tristearin. ·410 do. cerotic. ·6760 do. myricin. ·329 do. resin acids (ordinary colophony, chiefly sylvic acid).					

(8) The standard NaHO used was standardized with normal H_2SO_4.

VI.—*Note on an easy and rapid method of determining the Specific Gravity of Solids.* By James J. Dobbie, M.A., D.Sc., and John B. Hutcheson, Assistants to the Professor of Chemistry, University of Glasgow.

[Read before the Society, 2nd April, 1884.]

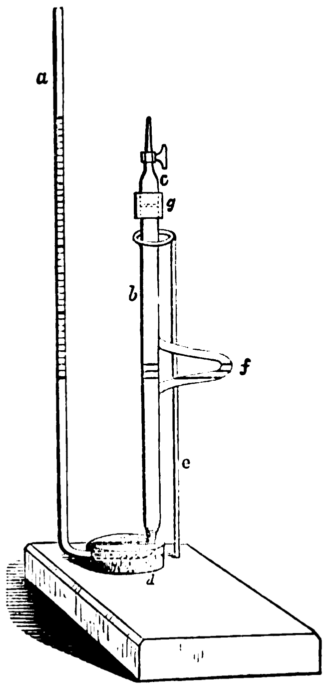
The specific gravity of a substance is the weight of a volume of that substance compared with that of an equal volume of some other substance selected as standard, and measured under the same conditions of temperature and pressure.

Water is the standard universally employed for solids and liquids. Hence, in taking the specific gravity of a solid, the data which have to be determined experimentally are the weight of a volume of the solid, and the weight of an equal volume of water. The weight of water is usually found by making use of the well-known principle that a solid, when weighed in a liquid, weighs less than in air, by the weight of the volume of liquid which it displaces. By subtracting, therefore, the weight of the solid in water from its weight in air, the weight of water displaced—*i.e.*, the weight of a volume of water equal to that of the solid, is found. For accuracy, this method leaves nothing to be desired; but the operation of weighing a solid in water is one which always involves some trouble, and frequently requires some delicacy of manipulation; and in the case of solids which are soluble in water, the weighing must be performed in some other liquid, and the gravity having been found relatively to that liquid must be reduced subsequently to the standard of water. In the case too of a solid which is lighter than water, the weighing must either be performed in a liquid of less specific gravity, or else a heavy body must be attached to sink it in water. Whichever method be employed, additional weighings are required, and subsequent calculation is involved.

The method which we now propose to describe, and which we have employed for some time in this laboratory, is applicable in all cases, and gives results which agree as closely with those obtained by the ordinary method as two different determinations by the ordinary method usually agree with one another.

Instead of finding the weight of water in the usual manner, we measure the volume of water displaced by the solid.

The accompanying figure shows the apparatus which we employ, which may be termed a specific gravity burette. It consists of an U tube, one limb of which, *a*, is of small diameter (about $\frac{3}{16}$ of an inch), the other, *b*, of large diameter. A piece of tubing, *c*, of the same diameter as *b*, and furnished with a stopcock, is joined to *b* by means of a piece of rubber tubing, *g*, so that it can be easily disconnected and joined again. A piece of cork or wood, *d*, with a groove cut in it, serves as a stand for the apparatus, which is further supported by the metal upright, *e*.



The small tube, *a*, is graduated from the point indicated on the figure to cubic centimetres (= grammes) or grains of water. Several lines are engraved on the tube, *b*, at the same level as the beginning of the graduation on *a*. The tube is filled with water or other liquid up to one of these lines.

The substance whose specific gravity is required, having been weighed, is placed in the tube, *b*, when, of course, it displaces its own volume of the liquid. The tube, *c*, is then attached, the stopcock is opened, and, by blowing through *c*, the level of the liquid in *b* is depressed below the beginning of the graduation. By means of the stopcock it is allowed to rise slowly again until it reaches the level at which it stood before the solid was introduced. In this way the total bulk of liquid displaced is measured in the tube, *a*, which, being of small diameter, admits of the volume being measured with great accuracy. If the tube is graduated to grains or grammes of water, the specific gravity of the substance is found directly by dividing the weight of the substance in air by the number of grains or grammes indicated on the scale of the instrument.

The Messrs. Gray, of the Physical Laboratory of this University, suggested to us that by attaching to the tube, *b*, a small tube in the form of a loop so placed as to have its limbs nearly at right angles to *b*, we should be able to bring back the water in *b* to its original level with much greater accuracy than by reading directly in the wide tube, even with the aid of a float, since a slight alteration in the level of the water gives a large horizontal displacement in the loop tube.

The following table will show the degree of accuracy which can be obtained by our method. Obviously to obtain good results with bodies of high specific gravity, as large a piece of substance as possible should be used.

	Specific Gravity. By Ordinary Method.	Specific Gravity. By New Method.	Difference.
Lead,	11·333	11·310	0·023 –
Copper,	8·090	8·090	——
Steel,	8·480	8·440	0·040 –
Zinc,	7·160	7·150	0·010 –
Glass,	2·456	2·452	0·004 –
Iron Ore,	3·232	3·240	0·008 +
Copper Pyrites,	4·762	4·756	0·006 –
Dolomite,	2·704	2·723	0·019 +
Quartz,	2·649	2·620	0.029 –
Malachite,	3·953	3·940	0·013 –
Granite,	2·629	2·611	0·018 –
Wax,	0·988	0·997	0·009 +
Cork,	0·202	0·201	0·001 –
Sugar,	1·404	1·404	——
Alum,	1·777	1·780	0·003 +

The advantages of the method are two-fold.

(1) Its rapidity.—Several determinations can be made by it in the time required for a single determination by the ordinary method.

(2) It is applicable to all solids.—In the case of bodies lighter than water, or soluble in water, the tube has only to be filled with the liquid appropriate to the substance. In every case, no matter what liquid is employed, the amount of rise in the tube will give the volume, and therefore the amount of water which the solid would displace. The rule for finding the specific gravity is always the same:—divide the weight of substance in air by the number of grains or grammes read off from the burette.

For entering into a description of so simple and obvious a contrivance, we make this apology. It is to be regretted, both on practical and scientific grounds, that chemists so seldom determine the physical constants of the numberless new salts, and other substances which pass through their hands. The reason undoubtedly is that physical experimental methods are usually troublesome and tedious. We have endeavoured to simplify one of the simplest and most beautiful of these methods, and shall be pleased if the apparatus we have described should facilitate the systematic description of the physical properties of new substances.

VII.—*Note on Mr. Joseph Whitley's Centrifugal Mode of Casting Steel Plates for Shipbuilding, &c.* By Dr. Henry Muirhead, President.

[Read before the Society, 2nd April, 1884.]

In 1878 and 1880 I read before this Society communications from Mr. Joseph Whitley, of Leeds, detailing experiments made by him, at my request, in reference to the change of volume taking place in metals and metalloids during the process of fusing. These communications, together with some account of experiments conducted by Mr. Thos. Wrightson, of Stockton-on-Tees, which I included in my second paper (see vol. XII., page 124), had an important influence in modifying the views held by the highest authorities as to the earth's surface cooling, crusting, cracking to pieces, and sinking into the molten interior of our globe in ante-geologic times. (See vol. X., page 145, and vol. XII., page 121, of our *Proceedings*, and other references given there.)

Mr. Whitley has recently erected large works at Leeds for the purpose of manufacturing, by a wholly new centrifugal method, steel plates for shipbuilding, steam-boilers, &c. As the process seems destined to work a revolution in that branch of manufacture, I have thought it of sufficient interest and importance to give you a slight outline of the procedure.

A hollow metal cylinder, lined with gannister or other brick, revolves at high speed, the axis being horizontal. A gutter or rhone, perforated with holes, passes into the interior along its whole length. Into this gutter is poured melted mild steel, which, escaping through the holes, is carried round by the swiftly-revolving case, and centrifugally is formed into an inner cylinder of steel of an inch or more in thickness. This cylinder, while still hot, is drawn out, cut across by a saw, put into a rolling mill, and rolled to the length and thickness required.

Mr. Whitley writes:—"Suppose I wish a plate for shipbuilding, then say, given a mould 5 feet in diameter and 5 feet long; in it I cast

a cylinder an inch thick. This, when taken out and cut, is fully 15 feet long and 5 feet broad. It is then rolled down to half an inch of thickness. Such a plate is then 30 feet long and 5 feet broad, for we can arrange that the displacement of the thickness shall be chiefly endwise. The present mould is 9′ long and 5′ diameter. With it yesterday (Friday, 7th March) I successfully cast a mild steel shell, weight of metal about 30 cwts. This makes the long-looked-for, but now no longer doubtful fact, a historic fact in metallurgical science. Hitherto these plates have been made from large ingots, which have been burnt on the outside while getting heated to the centre. It is the overheated portion that gives way in collisions, boiler burstings, &c. In my process the whole plate is homogeneous throughout, and the tensile strength is so much increased that when ships collide there is no rending or fracture, and though the bilge is made to collapse, the ship, still floating, can sail into port to get rebilged—re-contoured. Of course tubes of smaller size can also be manufactured centrifugally, and these are especially suitable for connections about steam-boilers, where, in lap-welded tubes, leakage is apt to take place at the overlap."

VIII.—*Presentation of a Model, in Bronze, of Cleopatra's Needle.* By Dr. Henry Muirhead, President.

[Read before the Society, 2nd April, 1884.]

Mr. Whitley has cast in bronze a very beautiful model of Cleopatra's Needle as it came from Egypt. It is accurately to scale, half an inch to the foot, so that, with compasses and foot-rule, one can find the size of any portion of the obelisk or its hieroglyphics. I had a visit from Mr. Whitley last month, and he very handsomely said, "I will make you a present of the model, on condition that you present it to the Philosophical Society of Glasgow," which I now have much pleasure in doing. You will observe that the model is mounted on a plated pedestal, on which he has engraved my name. The side with my name corresponds to that side of the monument fronting the Thames Embankment.

The Needle, with a fellow, which is still standing in Alexandria, was brought during times of Roman rule to that city from An (Heliopolis), the On of the Hebrews. Originally it was cut from one of the granite quarries of Syene, near the south of Upper Egypt. It is covered with hieroglyphics, in three columns, on each of its four sides. Of these the central and broadest columns are by Thothmes III., a sovereign of the 18th Egyptian dynasty, a great conqueror. His rule extended from Libya on the west to Babylonia on the east, and from Abyssinia on the south to the Isles of Greece and Armenia on the north. He reigned in the 16th century B.C. His wife Hasheps, who was also his sister, a woman of much ability, older than himself, not only metaphorically but actually wore the male garment, till death relieved him from her sway. He then cut her name from the monuments, pre-dating the commencement of his own reign.

The inscriptions on each side of the central columns are by Rameses II., the third sovereign of the 19th dynasty—the Sesostris of the Greeks, and "the greatest figure in the long line of the

Pharaohs," so that it happens that we have on this obelisk hieroglyphics of the two most powerful Egyptian monarchs that the world ever saw. The inscriptions are little else than titles and ascriptions to the solar deities of Egypt, as, for example, according to Dr. Samuel Birch's decipherment, on side towards the east, on Thames Embankment:—

Central Column.—The Horus, lord of the upper and lower country, the powerful bull crowned in the Uas or Thebes, the King of the North and South, Ramen Chepher, has made his monument to his father, Haremachu (Horus of the Horizons). He has set him up two great obelisks, capped with gold, at the first time of the festivals of thirty years, according to his wish he did it, the son of the Sun Thothmes (III.) type of types did it, beloved of Haremachu, ever living.

Left Column of same side.—The Horus of the upper lower country, the powerful bull beloved of the Sun, the King of Upper and Lower Egypt, Ra-user-ma, approved of the Sun, lord of the festivals, like Ptah-Tanen, son of the Sun, Rameses, beloved of Amen, a strong bull like the son of Nu (Osiris), whom none can withstand, the lord of the countries Ra-user-ma approved of the Sun, son of the Sun Ramessu (II.), beloved of Amen, giver of life, like the Sun.

IX.—*On a New Method of Measuring the Heat-conducting Power of various Materials, such as Cotton, Wool, Hair, &c.* By J. J. Coleman, F.I.C., F.C.S.

[Read before the Society, 23rd January, 1884.]

In the last edition of the "Encyclopædia Britannica" Sir Wm. Thomson calls attention (in the article "Heat") to unsatisfactory and inaccurate figures which have been put forward by Peclet as to the conducting power for heat of various solids. In regard to metals proper, more correct results have been achieved by the late Principal Forbes of Edinburgh, Professor Tait, and others. In all treatises upon heat Peclet's figures relating to the conducting powers of fibrous and spongy substances, such as cotton, wool, sawdust, &c., are assumed as correct, and possibly they may be, but they are deficient in giving practical information to those who require to construct insulated cold chambers for the preservation of ice, and similar technical purposes.

I have therefore had occasion to make a number of experiments on the subject, which, besides their practical utility, I venture to think are of scientific interest. The apparatus used in my first series of experiments, which were commenced in June, 1883, consisted of 10-inch cubes of thin tinplate filled with ice, placed inside 18-inch cubes of thin tinplate, the space between the two cubes being filled with the substance to be tested. (See Figs. 1 and 2.) A number of these cubes were placed side by side in a room kept at an uniform temperature of about 60° Fahr., the ice melted per hour being drawn off and measured, from which the quantity of heat penetrating into the ice was easily calculated. It will be seen that this apparatus in its general features resembles the "Lavoisier Calorimeter," designed for measuring specific heat, but I am not aware that this principle has been adopted before for measuring thermal conductivity. The results of the experiments are summarised in Table I.

No observations were taken until the vessels charged with ice had been about 18 hours in the constant temperature of the room, thus allowing equilibrium to be established. The melted ice was

Fig. 1.

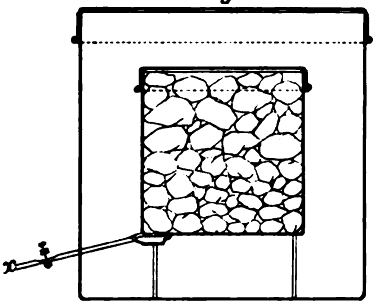


Fig. 2.

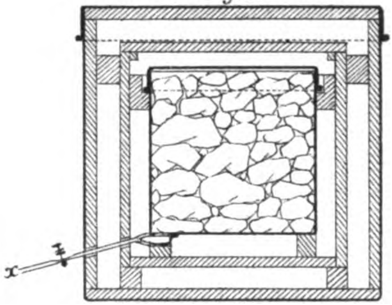


Fig. 3.

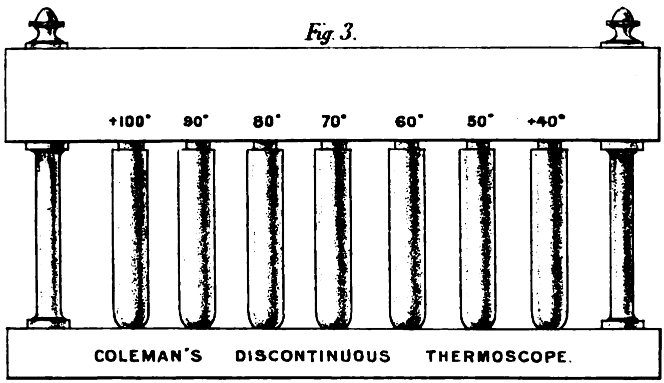


Fig. 4.

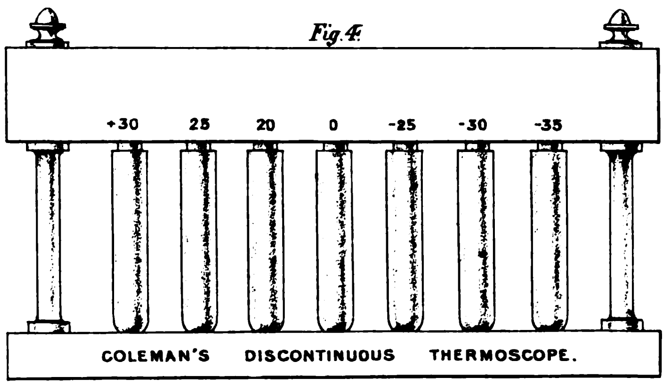


Fig. 1 & 2 illustrate Mr. Colemans Paper on Heat Conduction and Fig. 3 & 4 his paper on a New Thermometer or Thermoscope.

then carefully drawn off from the solid ice by the *India-rubber pipe x, provided with a clip,* at 10 A.M. of the 15th June, and the results during the subsequent 24 hours were taken as the most reliable, although for a still further period of 48 hours the observations were continued, and are recorded in the Table. All the materials were dried by keeping them in a loose state in a well-ventilated room, kept warm by an ordinary domestic fire for several weeks before the commencement of the experiments.

It was now thought desirable to make a similar series of experiments in a room kept at a temperature of about 100° Fahr. These were commenced on the 17th January, 1884, and continued until the 19th, and the results are recorded in Table II. herewith. The water drawn off during the first 10 hours is not included in the Table, which is confined to the results obtained between 11 A.M. of the 18th and 6.30 P.M. of the same day. Silicate cotton stands again at the head of the list; and it may be as well to explain that this interesting substance resembles cotton wool in appearance, and is produced in large quantities by blowing steam into melted blast-furnace slag. It is therefore a glassy fibre.

As it was an interesting matter to compare sheep's wool and cotton wool accurately, care was taken that the weight of material used in each case was exactly the same for a given space filled up—3 lbs. The figures of conductivity obtained represent the warmth of garments of equal thickness and equal weights. Of course, if with the two materials the weight of the garment per square foot is identical, but the thickness different from a different style of manufacture, then these figures will be modified.

As for technical purposes, charcoal is confined between walls of wood. A larger experiment was made in the room kept at 100°, the inner vessel of ice measuring 22 inches cube. This was surrounded by an outer layer of charcoal, three inches thick, and an outer wall of wood (deal) one inch thick. It was found that under these circumstances the ice melted at the rate of about 1 lb. per 24 hours for every superficial foot of insulation.

Although silicate cotton stands at the head of the list as an insulator, 10 inches thick being equivalent to say 12 or 15 inches of wood charcoal, it by no means follows that it is always the best substance to use. To begin with, it is four times, or perhaps six times, as costly as charcoal, and has the fault of being friable and liable to fall into powder, especially if used on board ship, from the incessant motion of the vessel when out at sea.

TABLE I.

EXPERIMENTS COMMENCED JUNE 14th, 1883—4.45 P.M.

Ice Melted with different Insulators Measured in Cubic Centimetres.

DATE.	SIL. COTTON.	HAIR FELT.	CHARCOAL.	WOOD SHAV.	BREEZE.	WOOD AND AIR SPACE.	TEMP. FAHR. OUTSIDE BOXES.
	C. C. Ice Melted.	C. C. Ice Melted.	C. C. Ice Melted.	C. C. Ice Melted.	C. C. Ice Melted.	C. C. Ice Melted.	
June 15th, 10 a.m., ...	893	807	800	745	1625	1560	63° Fahr.
,, ,, 6 p.m., ...	250	305	330	350	703	780	65° ,,
,, 16th, 10 a.m., ...	815	940	943	985	1810	2220	71° ,,
	1065	1245	1273	1335	2513	3000	
,, 18th, 10 a.m., ...	1540	1640	1870	1750	3050	3375	
	2605	2885	3143	3085	5563	6375	

Relative conducting power for Heat calculated from above data.

Silicate Cotton, ...	100	Wood Shavings, ...	125
Hair Felt, ...	117	Gas-works Breeze, ...	230
Charcoal, ...	120	Wood and Air Space,...	280

TABLE II.

EXPERIMENTS COMMENCED JANUARY 17TH, 1884—10.15 P.M.

Ice Melted with different Insulators Measured in Cubic Centimetres.

Date.	Silicate Cotton.		Cotton.		Wool.		Infusor. Earth.		Charcoal.		Sawdust.	
	C. C. Ice Melted.	Extern. Temp. Fh.	C. C. Ice Melted.	Extern. Temp. Fh.	C. C. Ice Melted.	Extern. Temp. Fh.	C. C. Ice Melted.	Extern. Temp. Fh.	C. C. Ice Melted.	Extern. Temp. Fh.	C. C. Ice Melted.	Extern. Temp. Fh.
Jan. 18th, 8 a.m. to 11 a.m.,	225	98°	252	97°	345	97°	350	98°	440	98°	440	98°
,, 2 p.m., ...	360	100°	385	99°	340	99°	360	100°	430	100°	445	100°
,, 5 p.m., ...	275	101°	355	101°	430	101°	390	102°	445	103°	450	103°
,, 6.30 p.m., ...	85	96°	105	95°	175	95°	185	96°	195	97°	205	97°
	945		1097		1290		1285		1510		1540	

Relative conducting power for Heat calculated from above data.

Silicate Cotton, ...	100	Infusorial Earth, ...	136
Cotton Wool, ...	122	Charcoal, ...	160
Sheep's Wool, ...	136	Sawdust, ...	163

Or the above results combined with those in Table I.

Silicate Cotton, ...	100	Charcoal, ...	140
Hair Felt, ...	117	Sawdust, ...	163
Cotton Wool, ...	122	Gas-works Breeze, ...	230
Sheep's Wool, ...	136	Wood and Air Space, ...	280
Infusorial Earth, ...	136		

X.—*On a New Thermometer or Thermoscope.* By J. J. Coleman, F.I.C., F.C.S.

[Read before the Society, 23rd January, 1884.]

Although the principle of an ordinary mercurial thermometer, spirit thermometer, or air thermometer, or even of a Breguet's metallic thermometer is such that any fraction of a degree of heat can be measured by the uniform rate of expansion, still, in *graduating* such thermometers two physical constants are used—namely, the freezing point of water and the boiling point of the same liquid—and it is these points that are marked on the instrument previous to graduation.

It is clear, therefore, that adopting the freezing point of a liquid or the melting point of a solid for measuring temperature is correct in theory, and that a series of such substances placed side by side in tubes could be employed for the purpose. Such an instrument Sir Wm. Thomson proposes should be called a "discontinuous intrinsic thermoscope." I am not aware of any such instrument having been hitherto practically constructed, from the difficulty there is in getting a series of solids having a gradual and minute difference in their melting points, or of liquids having gradual and minute differences in their freezing points. Glycerine, when absolutely pure, crystallizes not very much below the temperature of freezing water, but when it contains in admixture a trace of water it does not solidify until about 40° below zero of Fahr., and this solidification is not of a crystalline but of a buttery nature. By adding successive additions of water, liquids freezing at any intermediate point up to the freezing point of water can easily be prepared. Above the temperature of freezing of water, and extending up to 150° Fahr., we have paraffins (olefins), which can be readily obtained, having the property of congealing at any intermediate point.

These substances, therefore, offer a very fair means of construct-instruments capable of indicating through a range of 200°, and the range might be probably further increased by using alcohol to mix with the glycerine for temperatures lower than this range, and anthracene or some similar substance for temperatures higher than this range. The instruments I now submit to the Society are rather rough, inasmuch as they only show differences of less than 5° in temperature (see Figs. 3 and 4), but it is manifest that the tubes of which such an instrument consists can be multiplied to any extent, and made of very fine bore for scientific purposes, or they can be of several inches diameter, and say a foot or two in depth, so as to be avaible for use in public gardens, squares, and such like places. In any case, it is advisable to have them hermetically sealed.

The makers of such instruments would, in the first case, require to have large quantities of liquid made, and tested with a standard thermometer, after which the instruments could be turned out with facility and despatch from the stock kept of the various liquids.

XI.—*On the Measurement of Electric Currents and Potentials.* By Sir WILLIAM THOMSON, F.R.S.

[Read before the Society, 9th January, 1884.]

IN this communication, after referring to the electrometer as being, when available, in one form or other, the most proper instrument for measuring differences of electric potential (inasmuch as it disturbs the difference of potential to be measured not at all, because the insulation of the insulated part or parts may be made practically perfect), it was shown that the functions of an electrometer can, for many practical purposes, in a thoroughly satisfactory manner, be performed by means of a galvanometer of high resistance. Thus, galvanometers of from 200 or 300 to 30,000 ohms resistance can be very conveniently used for measuring differences of potentials of from 1 to 600 volts, provided that in each case the coil is not heated by the current produced in it so much as to cause more than allowable error by augmentation of its resistance. To obviate the need for a temperature correction on account of difference of atmospheric temperature it is necessary, for fairly satisfactory accuracy in ordinary practice, to have the coils of potential galvanometers made of German silver wire instead of copper. In cases, however, in which the sensibility obtainable by copper is desired, the galvanometer coils may be made of copper wire, but the proper temperature correction, amounting approximately to ·39 per cent. per degree centigrade, must be carefully applied. But there is no need for the sensibility obtainable by copper coils in almost any of the practical applications of electricity except telegraphy; and for general use in scientific laboratories, or in electrical factories, or in connection with electric light installations, the potential galvanometer ought to have its coils of German silver wire, because the increase of resistance for this alloy is only about ·04 per cent. per degree centigrade, and is less than for any other known and practically available metal.

The author showed a new form of potential galvanometer, with four German silver coils acting on the two needles of an astatic combination hung by a single silk fibre. The astatic combination has for most practical applications great advantage over the single needle galvanometer, in respect to liability to disturbance by magnets in its neighbourhood. The new form of astatic needle galvanometer, whether for current or potential, may be used even in close proximity to a dynamo machine without being sensibly disturbed. In this instrument the two needles of the astatic combination are controlled by two equal magnets, or combinations of magnets, symmetrically arranged, adjustable for zero, and adjustable in respect to power. The method for adjustment to any desired sensibility, for the potential galvanometer, through a wider range than can be conveniently given by the magnetic controller, is by the use of adjustable resistances placed in series with the coils of the galvanometer. A very convenient and ready appliance of this kind constituted part of a complete instrument shown to the Society and designated by the author a long-range potential galvanometer. After many years of trials and anxious thought, the author had come to prefer, for practical purposes, the use of a standard Daniell cell to any other means hitherto realised for standardising a potential galvanometer. Accordingly he has made, to be used in connection with the new galvanometer, a convenient form of a standard Daniell cell.

A specimen of the cell was shown to the Society. It consists of a shallow rectangular tray of sheet copper, which may be about 15 centimetres square, having vertical sides about 5 centimetres high. The vertical sides are, for electrical reasons, enamelled or painted, to prevent contact between them and the liquid of the cell. Within this tray is placed a zinc plate about 3 mm. thick, and 14 centimetres square, supported firmly in notches of four wooden blocks resting securely in the four corners of the tray. In the centre of the zinc plate is a hole about one centimetre diameter, through which the stem of a filler, long enough to reach the bottom of the tray, passes, and which is used to pour into the bottom of the tray a measured quantity of a saturated solution of sulphate of copper. The tube of the filler is very fine, and the capacity of the wide part is sufficient to hold the whole amount of copper solution, which is poured quickly into the filler, and flows slowly out of it in the course of about a minute, so as to spread slowly over the bottom of the cell. The wide part of the filler is flat, so

as to let it rest stably on the top of the zinc plate. To set up in action this cell, a solution of sulphate of zinc of 1·02 specific gravity is poured into the tray so as to fill it as high up as the zinc plate, and by means of the filler a concentrated solution of sulphate of copper, sufficient in quantity to make a layer of about half a centimetre deep, is poured in along the bottom of the tray.

The instrument, without any resistance added to its coil, is of good sensibility for a single cell. In this condition its coefficient is determined. Then a very simple calculation, or a table of numbers, tells the proper quantity of resistance to be added in order to give exactly the right sensibility with single divisions or round numbers of divisions, corresponding to single volts or round numbers of volts, according to convenience, in the special application for which the instrument is wanted. The user can always, with great ease, and with very little expenditure of time, standardise his own instrument in this manner by aid of a standard cell and standard solutions which are supplied along with the instrument.

The pointer by which the deflections are indicated consists of a light tube of aluminium with one end shaped to a fine edge, by which the deflection is read on a circular scale, divided and numbered, as in the author's graded galvanometers, according to tangents of angles of deflection. As in those previous instruments, the scale is of paper pasted on a horizontal mirror, by aid of which error from parallax is avoided with great ease in taking the readings. To the other end of this pointer is attached about a centimetre of fine platinum wire, turned downwards so as to dip about a quarter of a centimetre below the surface of a large flat dish of heavy paraffin oil, with which a little olive oil may be mixed when more of viscous resistance than is given by the paraffin is desired. The author has found that by this means a most satisfactory dead-beat effect is obtained, without any sensible error in respect to the position of equilibrium, whether for zero or for the deflection produced by a current. A properly shaped metallic pipette bottle, by which, when the galvanometer is to be moved at any time, the oil may be drawn off from the oil-vessel with great ease, carried away without risk of losing any of it, and replaced in the vessel in the galvanometer, is supplied with the instrument. To make the galvanometer itself portable, the framework carrying the steel needles and pointer, which is hung by a silk fibre when the instrument is in use, is let down by aid of a screw so as to hang upon a

brass pin, passing through a ring which forms part of the framework. In this condition the instrument may be turned upside down or carried about in the roughest way, without the possibility of breaking the silk fibre. To set the instrument in action all that is necessary is to place it in position and level it, and by the screw pull up the upper end of the fibre to its proper position.

A current galvanometer, with portable silk fibre suspension, oil vessel to give the dead-heat quality, astatic needles acted on by two circular coils in the main circuit surrounding the two needles respectively, and two magnetic systems of controlling magnets acting symmetrically on the two needles, was shown to the Society, This instrument is in all respects exceedingly convenient for the practical measurement of currents, except for the comparative difficulty of standardising from time to time, necessary on account of the inconstancy of the steel magnets. This may be done electrolytically, with sufficient accuracy for most practical purposes, by weighing the deposit of copper from a solution of sulphate of copper, in the manner described at the end of Chap. VII. of Mr. Andrew Gray's book, "Absolute Measurements in Electricity and Magnetism" (Macmillan, 1884). The process is, however, somewhat troublesome, and takes a good deal of time. The standardising may be done with much greater ease by comparison with a standard current meter on the principle of Weber's electro-dynamometer. A very valuable and convenient instrument of this class, Siemens' well-known electro-dynamometer, with its novel and ingenious method for measuring torque by means of a spiral spring acting on the moveable coil or arc, which is suspended by a silk thread passing down along the axis of the spring from a fixed point above, and has its two ends dipping in cups of mercury below in the same vertical with the bearing thread, was shown to the Society.

Among the instruments shown to the Society was also a Siemens-Watts' meter, which is the same as his electro-dynamometer except that the fixed coil, instead of being of a small number of turns of thick copper wire in the main circuit, is of a very large number of turns of very fine German silver wire, connected by its two ends to two points of the main circuit, between which the measurement in Watts, of the electrical activity of the current, is to be made. The moveable coil is, by means of its cups of mercury, joined in series with the main circuit. The instrument is an exceedingly convenient and valuable realisation of an idea which has no doubt

occurred to many electricians,* but which, so far as the author knew, was first published by Prof. John Perry in the *Journal of the Society of Arts* for April 15, 1881, as embodied in an instrument designed by Prof. Ayrton and himself.

The author remarked upon the great want which existed of a name for the unit of conductivity. He repeated a suggestion which he had made in his lecture on "Electrical Units of Measurements," delivered before the Institute of Civil Engineers in London, on 3rd May, 1883, that the name "mho" might be adopted for the unit of conductivity corresponding to the resistance of one ohm. He showed to the Society a new instrument which he had designed, and which he termed a mho-meter. It illustrated the great advantages in using the conductivity method in many electric measurements.

This instrument is simply an astatic-needle current galvanometer, with the steel controlling-magnets replaced by coils of very fine German silver or copper wire, placed perpendicularly to the galvanometer coils proper. The two ends of the controlling coils are put in metallic connection with two points of a conductor, between which the conductivity is to be determined, the conductivity to be measured being exceedingly great in comparison with that of the controlling coils. The galvanometer coils proper are connected, so that the whole current through them passes through the conductor whose conductivity is to be measured, except the small part of it which goes through the controlling coils. With these connections it is clear that the conductivity to be tested is equal to an absolute constant multiplied into the conductivity of the controlling coils and into the tangent of the angle of deflection. One main object of the instrument is to give a ready measurement of the conductivity of dynamo armatures and electric light mains, or of specimens of copper submitted for tests of their specific conductivity. For this application the controlling coils are made of copper, so that no temperature correction may be required (provided the temperature of the galvanometer is approximately enough the same as that of the conductor tested), and the instrument thus made may be called a "copper conductivity meter."

* Prof. Perry, *Journal of the Society of Arts* for 15th April, 1881; Sir William Thomson and Profs. Ayrton and Perry, British Association Report, York, 1881, and *Journal of Society of Telegraph Engineers and Electricians*, Vol. XI., May, 1882.

When the object is to measure electric light currents, the controlling coils are made of German silver wire, and are fixed in series with an adjustable resistance, also of fine German silver wire, so wound in a convenient position in the base of the instrument as to exert no electro-magnetic force on the needles. In this instrument the conductivity of the controlling coils, and of the resistance wire in series with them, varies so little with the practical variations of temperature that the conductivity to be measured is, for most practical purposes, given with amply sufficient accuracy by the tangent of the deflection multiplied by an absolutely constant coefficient. The added resistance may be adjusted to make this coefficient such that one division corresponds to a mho, or a decamho, or a hectamho, or to any other value, within a wide range, which may be found convenient. It may, for example, be adjusted to give deflections at the rate of one division per lamp, and for this application the instrument may conveniently be called a "lamp meter."

The author has such an instrument now in use on the lighting system of his house, in which varying numbers of from 1 to 40 Swan lamps, some of the old type, 42 volts, and some of the new type, but of only 84 volts (instead of the 110, which of course would be preferable if it were not for the old lamps, which he has had in use for two years, and which he wishes to keep in use for as many years longer as they will last). It is beautiful to see the pointer moving up two divisions when a pair of the old lamps in series, and by one division when one lamp of the new type is lighted, and falling similarly when any number of the lamps are extinguished; and it is very useful to be able, merely by looking at the instrument, to tell how many lamps are lighted at any time. The inequality of the lamps gives scarcely an uncertainty of one lamp in the whole number when 30 or 40 are incandesced.

The potential galvanometer, which is also always kept on the mains, shows considerable inequalities (checked always, in the course of a few seconds, by the author's potential regulator, with its pair of mutually-geared horizontal cog-wheels dipping on one side or the other, according as the potential is too high or too low, into a hollow centrifugal cylinder of oil rotating rapidly round them), but the pointer of the lamp meter remains absolutely unmoved (or rather, with absolutely no perceptible motion) throughout these inequalities.

XII.—Dr. ALLEN THOMSON.

[Read before the Society, 30th April, 1884.]

Allen Thomson was born in Edinburgh, on the 2nd of April, 1809, and he died in London, on the 21st of March, 1884, having thus nearly completed his seventy-fifth year. For nearly half a century he held a prominent position among scientific men, and for thirty years he was closely connected with Glasgow, as an eminent citizen who took his part in promoting the common well-being, and as one of the most distinguished professors in the university. Further, as for thirty-five years he was a member of our Society, and at one time its President, it is becoming and respectful to his memory that at a Meeting of the Philosophical Society of Glasgow there should be read an account of who he was and what he did.

He was the son of Dr. John Thomson, who became successively Professor of Military Surgery and of Medicine and General Pathology in the University of Edinburgh, and of Margaret, the third daughter of John Millar, Advocate, who was Professor of Law in the University of Glasgow in the latter half of last century (from 1761 to 1801). Allen Thomson wrote a biographical notice of his father,* from which we learn that his grandfather was a silk weaver, who came from Kinross, where at one time he was rather prosperous in the world. Adverse circumstances compelled his grandfather to settle in Paisley, where for many years he had a struggle in rearing his family. John Thomson, one of the sons (born 1765—died 1846), was apprenticed to his father's trade, but, like many a Scotch youth, he loved learning, and strove

* John Thomson's "Life of Cullen," 2nd edition, 1859.

to get it under adverse circumstances.* His father, who was an Anti-burgher Seceder, hoped to see his son John a minister in that worthy body of dissenters, and was not a little annoyed when he found he had a strong predilection for the study of medicine. However, he gave way, and John Thomson, after studying in Glasgow and Edinburgh, became one of the foremost physicians and pathologists of his time, and occupied two chairs successively in the University of Edinburgh, both of which were founded on his recommendation.† He was a man of great erudition and force of character, and he made important contributions to the medical science of his day.

Whilst he was a House-Surgeon in the Royal Infirmary of Edinburgh, John Thomson became the friend of John Allen,‡ who at one time lectured on physiology in Edinburgh, and who afterwards, drifting into a politico-literary career, became the private secretary and confidential friend of Lord Holland. This John Allen was in his day a prolific writer on political subjects, but he is probably best known as the author of the well-known book on the "Rise and Growth of the Royal Prerogative in England." His name was given to the subject of this memoir, and thus we can trace the origin of the familiar name of Allen Thomson.

John Thomson was twice married. By his first marriage he had three children, the most remarkable of whom was Dr. William Thomson, who was Professor of Medicine in the University of Glasgow from 1841 to 1852; and by the second marriage he became the father of Allen Thomson. The home in which Allen Thomson was reared in Edinburgh was no doubt one of plain living and high thinking, as his father must have had the same kind of struggle as all must encounter who aim at establishing a professional and scientific reputation in Edinburgh, where the contest is always keen and the prizes few. Of this period of

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* "Professor Thomson was originally intended to be a weaver, and laid the foundation of his future eminence by laborious study while following that occupation. He had the books he was studying always lying open at the side of his loom, and he never lost a moment he could spare in making use of them."—Biographical notice of John Allen, prefixed to "Inquiry into the Rise and Growth of the Royal Prerogative in England," by John Allen, 1849.

† Sir Alexander Grant's "Story of the University of Edinburgh Vol. II., p. 441.

‡ John Allen, born at Redfoord, Parish of Colinton, near Edinburgh, 3rd February, 1771; died 10th April, 1843.

Allen Thomson's career we have an interesting reminiscence just published in the "Memoirs of Life and Work" of Dr. C. J. B. Williams, who states that in 1820 he was a pupil resident in the house of Dr. John Thomson, first in John Street, Canongate, and afterwards at Minto House, Argyll Square.* He says:—"He received from six to eight other pupils. We were well fed, and generally made comfortable, and I must say that I was always treated with kindness by both Dr. and Mrs. Thomson, and during the whole of my stay of four years we never had any disagreement. It was not so with some of the other students, and there were many changes of companions during my sojourn." At this period, Allen Thomson was about eleven years of age, and it is interesting to have a glimpse of the circumstances of his father's household, given us by one still alive, who sixty-four years ago was one of the family.

Allen Thomson was educated at the High School and University of Edinburgh and at Paris, and he graduated as Doctor of Medicine at the University of Edinburgh in 1830. It is significant of the bent of his mind towards embryology, the department of science in which he afterwards acquired honourable distinction, that his graduation thesis was "On the Development of the Vascular System in the Fœtus of Vertebrated Animals."† At the time of graduation he was President of the Royal Medical Society, a students' society which has contributed not a little to the fame of the medical school of Edinburgh, inasmuch as in the roll of its Presidents will be found the names of many who in after life became leaders in the profession. The year after graduation—1831—he became a Fellow of the Royal College of Surgeons, and he travelled on the Continent, especially in Holland and Germany. During this tour he visited many anatomical and pathological museums, and took elaborate notes of what he saw. This appears to have been a practice in early life, and I have before me many note-books full of details, carefully recorded in the neat handwriting which was characteristic of him up to nearly the end of his life. These notes are descriptions of special preparations anatomical and pathological, with shrewd critical remarks.

On his return to Edinburgh he started as an extra-academical lecturer on anatomy and physiology. In this undertaking he was associated with the late Dr. William Sharpey, who ultimately

* "Memoirs of Life and Work," by Dr. C. J. B. Williams. 1884.

† *Edinburgh New Philosophical Journal*, 1830, p. 295.

became Professor of Physiology in University College, London, and with whom Dr. Thomson maintained a life-long friendship of the closest possible character. In those days it was no light undertaking to become a teacher of anatomy in Edinburgh. The Anatomy Act was not passed till 1832, and the public mind was still excited by the notorious proceedings of Burke and Hare. In the University, the third Munro filled the Chair of Anatomy, but the great bulk of the students flocked to listen to the brilliant prelections of the celebrated Robert Knox, who in one year about this period had an extra-mural class numbering 504. Knox was unrivalled as a lecturer, and, as he brought his powers of ridicule and sarcasm to bear on all opponents, Dr. Thomson and his coadjutor came in for their full share.* About this time also a number of men, who afterwards became famous, were either students or extra-mural teachers, and there was the keen contest of able intellects, and the rivalry of a noble ambition. It is sufficient to mention the names of John Reid, John Goodsir, Edward Forbes, William B. Carpenter, and John Hughes Bennett. All became distinguished in biological science, and in such an atmosphere of thought it is no wonder that Allen Thomson was encouraged to prosecute a purely scientific career. None of these remain except Dr. Carpenter, who must feel that the death of his friend Allen Thomson is the severance of another link connecting him with what was undoubtedly a brilliant epoch in the history of the Edinburgh medical school.

In 1833 he travelled for nearly three months with his father on the Continent, visiting the principal medical schools in Holland, Germany, Italy, and France. It is very interesting to find, in his brief but carefully written Journal, that he saw and conversed with some of the most famous men of the period. Thus at Bonn he saw Treviranus (the younger), Bischoff, Neumann, and Mayer. He visited an Insane institution at Sieburg under the care of a Dr. Jacobi, and was specially impressed by the amount of freedom allowed to the patients; but there are still indications of irrational practice, as when he notes:—"The wheeling chair is not often used." At Heidelberg he visited Tiedemann, and carefully inspected his museum. Here he also saw Naegele, celebrated in obstetrical practice. At Tubingen he saw Autenrieth, and at Freyburg, Leuckhart, so well-known from his investigations into

* See "Life of Robert Knox, the Anatomist," by Henry Lonsdale, 1870, p. 262.

the history of intestinal worms. At Zürich he heard clinical lectures from Schönlein, one of the leaders in the German clinic. Here he also saw Oken, the leader of the school of what was then termed transcendental anatomy, and who disputed with Goethe the honour of being the discoverer of the vertebral construction of the skull. Obliged to leave Germany on account of political feeling, Oken had accepted the office of rector and of professor in the recently established University of Zürich. At Parma we find him recording :—"The University is in great part broken up, and about half of the building is occupied as a barracks for soldiers, in order to repress the revolutionary spirit of the students." At Bologna, the birth-place of modern electrical science, the scene of Galvani's labours, we find him stating :—"They have immense electrical and galvanic apparatus, also some electro-magnetic. The lecture room is a fine one, though for seeing the experiments the students are rather far off. The University is at present in disgrace, and no lectures are allowed to be given in it except the experimental ones, or more particularly the Anatomical, which could not be removed to another place. The other professors are obliged to give their lectures at their own homes. Soldiers are placed at the door of the University." This gives one a glimpse of the state of matters whilst Italy was under the yoke of the Austrian, and it is a satisfaction to know that the Italians, in their present regime of political freedom, now contribute their fair share to all departments of scientific progress. During the homeward journey Allen Thomson and his father specially visited Lyons and Paris, but the journals are not so full of detail regarding these places.

During a part of 1837 he travelled on the Continent with the then Duke of Bedford, and in a journal he has left records chiefly of Paris. The Duke appears to have been an invalid, with a dash of hypochondriasis, and it must have been no easy matter to meet his whims and fancies. Judging also from the record of the treatment carefully recorded by Dr. Thomson, we cannot help thinking that the Duke might possibly have been in a better state of health had he received less opium, blue pill, and black draught, all of which, however, were given quite in accordance with the professional views of the period. It is more interesting to turn from the account of his noble patient to that of a visit made to a meeting of the Académie des Sciences, where we are thrown in imagination into the society of the great scientific Frenchmen, not of the last generation but of the one immediately preceding it.

He writes:—"Went at ½ past 2 to a Meeting of the Académie des Sciences at the Institute. Heard several reports, and M. Biot made remarks on polarization, but did not hear him well. M. Magendie showed a man who was under treatment for deaf and dumb affection by passing currents of electricity through the nerves and with considerable success. Mentioned several cases of amaurosis in which electricity has been beneficial. I saw the following men of note:—Arago, Gay Lussac, Dulong, Biot, Geoff. St. Hilaire, Isidore St. Hilaire, Becquerel, Magendie, Chevreul, Lassaigne, Audouin, Milne-Edwards, Savart, Flourens, Dutrochet, Larrey, Sevres, Blainville, Breschet, Dumas, Duméril, Cagniard de la Tour, Payon, and others whose names I forget. Flourens presided, supported on the right by Arago, and on the left by Magendie and Becquerel. The whole seance was conducted with a great deal of philosophical propriety, whilst it was business like." This was on the 18th of December, 1837, forty-seven years ago, and there still lives one of that distinguished group, the veteran chemist and physicist, Chevreul, now in his ninety-eighth year, whose thoughts are no doubt well expressed by the poet:—

"When I remember all
The friends, so linked together,
I've seen around me fall
Like leaves in wintry weather;
I feel like one
Who treads alone
Some banquet hall deserted,
Whose lights are fled,
Whose garlands dead,
And all but he departed!" *

The year 1839 saw Allen Thomson appointed Professor of Anatomy in the Marischal College and University of Aberdeen; but in 1841 he resigned that office, and again became a teacher of Anatomy in the extra-mural school in Edinburgh. In 1841 Professor Alison resigned the Chair of Institutes of Medicine or Physiology in the University, and in 1842, after a severe contest with competitors no less formidable than Robert Knox, John Reid, and William B. Carpenter, Dr. Thomson was appointed his successor. At this period the patronage of the chairs lay in the hands of members of the Town Council, and if their appointments were on the whole very good, they gave occasion for making the

* "Light of other days." T. Moore.

election to a chair in the University not unfrequently a party fight, in which the testimonial and private influence systems were carried to an extent almost unknown in our day.

He held the chair in Edinburgh for six years, and during this time made several important contributions to the science of Embryology. These researches were more morphological than physiological; that is, they had to do more with development of form than with development of function, and they clearly indicated that Dr. Thomson's mind inclined more to the anatomical than to the physiological side of biology. It was not surprising, therefore, that when an opportunity offered, he should return to his first love, Anatomy. This was accomplished by his appointment to the Chair of Anatomy in the University of Glasgow in 1848, when he succeeded Dr. James Jeffray. He had now the unique experience of having been a Professor in three out of the four Scottish Universities. This chair he held with great distinction for 29 years, resigning it in 1877, when he was succeeded by my distinguished colleague, Professor Cleland. During these years he was an indefatigable worker, not merely in connection with the immediate duties of his chair, but as a contributor to scientific literature. His early work brought him reputation as an embryologist, and he kept it up by many important papers on the same department of science. In addition, he wrote on physiological optics, more especially on the mechanism by which the eye accommodates or focusses itself for objects at different distances. He was one of the first also to bring under the notice of British physiologists the researches of the Webers on the tactile sensibility of the skin, and he wrote largely for the great anatomical and physiological cyclopædia edited by Dr. Todd. His name will also be long associated with Quain's "System of Human Anatomy." He was the principal editor of the descriptive part of the seventh and eighth editions. In the seventh edition he was associated with Professor Sharpey and Professor Cleland; in the eighth with Professor Sharpey and Professor Schäfer; and in the ninth and last with Professor Schäfer and Professor Thane, both of University College, London. It is well known that Dr. Thomson, both with pen and pencil, made important additions to this great work.

During his career Dr. Thomson received many scientific honours. He was elected a Fellow of the Royal Society of Edinburgh in 1838, and of the Royal Society of London in 1848, and after his

removal to London in 1877, he became first a councillor of the Royal Society, and ultimately one of the vice-presidents. He became a member of the Philosophical Society of Glasgow on 1st December, 1849, being recommended by Dr. Thomas Thomson, Dr. R. D. Thomson, and Dr. Andrew Buchanan, and he was raised to the office of President in 1854. He also filled the office of President of the Medico-Chirurgical Society, and of the Science Lectures Association in Glasgow. In our city, also, he was the first President of the Local Branch of the British Medical Association. He was for 18 years a member of the General Medical Council, where his ripe experience and calm judgment enabled him to do good service to the cause of medical education. In 1871 he was President of the Biological Section of the British Association at the meeting in Edinburgh; and in 1876 the Association conferred on him its highest honour by electing him to the Presidential Chair. This he filled with much acceptance in 1877 at the meeting at Plymouth, when he delivered an able address on his favourite subject, "The Development of the Forms of Natural Life." In 1871 Dr. Thomson received from Edinburgh the degree of LL.D. This degree was also conferred by Glasgow University in 1877; and in 1882 he received the degree of D.C.L. from the University of Oxford. Latterly, also, he was elected to at least one Syndicate of the University of Cambridge, to assist in the election of professors to biological chairs—a high mark of the confidence reposed in his judgment by the University.

Whilst thus pursuing a scientific career, Dr. Allen Thomson was well known for many years as one of the most active and influential men in the city of Glasgow. He was always ready to aid in any good cause, and he took a prominent part in various great public undertakings. In particular, he acted as chairman of the Removal and Buildings Committee of the University of Glasgow from 1863 to 1874, which led to the erection of the University Buildings on Gilmorehill, and it is not too much to say that the carrying out of this great scheme was largely due to his energy and tact, and to the confidence reposed in him, both by the merchants of Glasgow and by his colleagues in the Senatus. A full account of all matters relating to the University of Glasgow New Buildings will be found in a "Report by the Chairman of the University Removal Committee."* This report was written by Dr. Allen Thomson, and

* Glasgow: Bell & Bain, 41 Mitchell Street, 1877.

was presented by him to the senate of the University on his resigning the office of chairman of the Removal and Buildings Committee, which he had held since 1863. It is to be regretted that Dr. Thomson and those consulting with him did not make sufficient allowance for the probable increase in the number of students, and that, therefore, the class-rooms and laboratories are already too small. Still, we must recollect that it is easy to be wise after the event, and that at the time Dr. Thomson superintended the drawing of the plans there was no reasonable likelihood the increase in students would be so great as it has proved to be, and we must, therefore, not be too critical regarding the proceedings of the man whose energy, influence, and tact, did much to get for Glasgow the splendid University Buildings she possesses.

Keenly alive also to the interests of the medical school of the University, and to the growing needs of the west end of the city and suburbs, Dr. Thomson took an active part in the erection of the Western Infirmary. This noble institution is a model hospital, and during its earlier years Dr. Allen Thomson, as a member of the Board of Directors, assisted in making it what it is. The best evidence of this is the following extract from the Minutes of the Board of Managers of the Western Infirmary:—

> "At Glasgow, and within the Secretary's Office, 11 Bothwell Street, the 25th day of March, 1884, at 10.15 a.m.
>
> "Being a Meeting of the Board of Managers of the Glasgow Western Infirmary.
>
> "JAMES HAMILTON, Esq., in the Chair.

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"The Chairman also made feeling reference to the death of Dr. Allen Thomson. Dr. Thomson had been one of the most zealous promoters of the scheme to establish the Western Infirmary. He was also a Member of the first Board of Managers, in which capacity he continued to act till November of 1876, when he removed to London. During this period Dr. Thomson's wide experience in Hospital Management, combined with his judicious and kindly manner in dealing with difficult and sometimes delicate questions, were of infinite value to the Institution. Though Dr. Thomson had removed to London, he was always glad to hear of the prosperity of the Infirmary, and he (the Chairman) believed he expressed the sentiments of every one present when he moved that a formal expression of their sympathy be sent to Mrs. Thomson and family. Mr. Hannay also referred to Dr. Thomson in similar terms, and the proposal was unanimously agreed to."

It is well known that he was especially proud of having been connected with these two great undertakings—the University

Buildings and the Western Infirmary—and it is not unlikely that their successful completion brought more happiness and solace to his mind than the reception of his numerous scientific honours.

It is somewhat difficult to give a critical estimate of Dr. Thomson's position as a man of science. As already stated, it was in the field of embryology that he won his laurels. His first paper on this subject was his Inaugural Dissertation or Thesis on taking the degree of Doctor of Medicine in the University of Edinburgh in July, 1830, and is entitled, "On the Development of the Vascular System in the Fœtus of Vertebrated Animals." It deals chiefly with an account of the early changes following impregnation, and is an excellent *resumé* of the state of scientific opinion up to that date. The older authors were aware that ova were found in the oviduct and uterus, and that they were derived from the Graafian vesicle, but it was not until 1827 that Von Baer discovered the mammalian ovum in the Graafian vesicle of the dog. Previous to this time, Caspar Frederick Wolff, of St. Petersburg, in 1759, and Christian Pander, at Würzburg, in 1817, had so far traced the development of organs; but they were ignorant of the earlier changes, and we date the rise of modern embryology from the discovery of Von Baer in 1827. The germinal vesicle in the ovum of birds was discovered by Purkinje in 1825, in mammals by Coste in 1834, and by Wharton Jones about the same period, whilst the germinal spot was first observed by Wagner in 1834. The division of the yolk after fecundation was first noticed in the ova of frogs by Prevost and Dumas, and afterwards by Rusconi, Baumgaertner, and Von Baer, and more particularly described by the latter. Changes in the cells of the yolk, or of the portion of it now called the blastoderm or germinal membrane, were first studied by Schwann about 1835, and he also made the important observation that the ovum itself is a cell. The division of these cells into two layers or laminae—the upper the serous, and the lower the mucous, now called respectively the epiblast and the hypoblast—was traced by Von Baer between 1833 and 1835. The next great steps were taken by Von Bischoff, who, between 1842 and 1854, traced the development of the mammalia; and by Remak, whose works on the development of birds and batrachia appeared from 1850 to 1855.*

* For an interesting historical account of these discoveries, see Allen Thomson's article, "Embryology," in the ninth edition of the "Encyclopædia Britannica."

Now, it cannot be said that Allen Thomson's name will be associated with any particular discovery in this department of science, but he did more than anyone between 1830 and 1850 to make the researches of the Germans familiar to his countrymen. Prior to 1830 little was known of embryological science in this country, and even between 1830 and 1845 almost its only expositor was Allen Thomson.* But he was more than a mere expositor of the German writers. His papers abundantly show evidence of personal investigation and critical inquiry. It was this that gave his writings permanent value, and constituted him an authority in one of the most difficult departments of science. He grasped firmly many of the problems of embryology, and he saw clearly that they were to be solved by patient inquiry into the development of all animal forms. Thus the comparative method had always great attractions for him, and it gave zest and breadth to his studies. This is evident in all his writings, more especially in the important articles he wrote for Todd's "Cyclopædia of Anatomy and Physiology." Thus, so long ago as 1844, we find him alluded to in these terms in "Wagner's Physiology":—"The best and most comprehensive view of the whole subject of generation, grounded on personal observation, which we possess is that by Dr. Allen Thomson, in his article 'Generation,' in Todd's 'Cyclopædia of Anatomy and Physiology,' vol. ii."†

Throughout life he worked hard to keep pace with the rapid progress of embryological science, and no one rejoiced more at the attention given to it by a rising school of British embryologists, nor mourned more deeply over the sad death on the Alps of its leader, the late Francis M. Balfour, of Cambridge.

It would serve no useful purpose to enter into a critical estimate of all his writings, a list of which I append to this account of his life. In his embryological papers he traced chiefly the development of organs, more especially those of the circulation and of the genito-urinary system; and, as he was an able draughtsman, he has stereotyped his conceptions in diagrams, still met with in almost every text-book of anatomy and physiology. Probably the most important of his other writings are those on the mechanism of accommodation

* Other two workers in this field ought to be mentioned—Martin Barry and T. Wharton Jones.

† "Wagner's Elements of Physiology," translated by Robert Willis. London, 1844.

of the eye, in which there is a great store of information as to the opinions of the older authors on this subject, and in which he makes a critical examination of the views of Cramer, Donders, and Helmholtz. He repeated many of the experiments of these distinguished observers, and corroborated their results. All his writings were characterised more by fulness of knowledge, clearness of statement, and soundness of judgment than by originality. The only weak feature of his mental development was an excess of caution in coming to a conclusion. This prevented him from making any broad generalisation with which his name will be associated.

Allen Thomson took a deep interest in many departments of science. He was not a specialist, as some suppose. He was a naturalist in the truest and best sense, and in a sense not understood so well in these days, when the very extent of knowledge sometimes seems to force men to become narrow and contracted in their views of the universe. Hence, he entered warmly into all scientific questions, and long he pondered on some of the problems towards the solution of which all science is tending. He might well say with Wordsworth:—

> "For I have learned
> To look on Nature, not as in the hour
> Of thoughtless youth; but hearing oftentimes
> The still, sad music of humanity,
> Nor harsh nor grating, though of ample power
> To chasten and subdue. And I have felt
> A presence that disturbs me with the joy
> Of elevated thoughts; a sense sublime
> Of something far more deeply interfused.
> Whose dwelling is the light of setting suns,
> And the round ocean, and the living air,
> And the blue sky, and in the mind of men:
> A motion and a spirit, that impels
> All thinking things, all objects of all thought,
> And rolls through all things."*

He was a ready listener, and he was always delighted to hear an account of a new investigation. Eager in the pursuit of truth himself, he above all things demanded accuracy, and sometimes he was apt to disconcert a beginner by doubting some of the alleged facts, or by offering arguments against the view placed before him. He was critical in all such questions, and it required a great deal

* Lines composed a few miles above Tintern Abbey, on revisiting the banks of the Wye during a tour.—William Wordsworth.

of fact and argument to lead him to a change of scientific opinion. Yet his mind was open and receptive, and he did not shrink from a change of view, although it went against his preconceived notions. As an example of this I may mention his general acceptance of the important generalisations of Darwin.

His own writings are models of clearness of statement and skilful marshalling of facts—indeed, to such an extent are these qualities developed as to give an unnecessary baldness to some of his papers. Dr. Thomson's mode of teaching was of the same character. Method, order, precision of statement, close reasoning, shone in every lecture, and there was also the persuasive eloquence of a quiet enthusiasm which captivated the listener. This was noticeable even in a popular lecture, as, for example, in the lecture on the brain he delivered some years ago in Glasgow before the Science Lectures Association, where the stately march of his sentences indicates a style as different as can be from the colloquial method of the common popular lecture.

He was wise in council, and his long experience, conveyed in a quiet, persuasive tone of voice, often cut the knot in troublesome questions. He had a strong faith in delay in coming to a decision on disputed points if the decision was likely to cause rancour and ill-feeling; and if this temporising spirit sometimes led to further difficulties and complications, it as often turned away wrath, and gave men time to consider the question more fully. He was thus a peacemaker, whilst at the same time, by patience and tact, he frequently was able to carry out precisely the policy on which his heart was set. In the social circle there was much gentleness and simplicity of manner, along with a keen sense of humour. It would be impertinent to say anything more of his domestic life than that it was characterised by a quiet kindliness, and that chivalrous attention to little details of personal courtesy which mark the true gentleman. His qualities of head and heart, however, do not require to be set forth. One can never forget the kindly courtesy, the simplicity of address, the indescribable charm of his manner, the warmth of his friendship. I saw him a few weeks before his death, and it was touching to find the aged anatomist paying the penalty of his knowledge by being able to trace the neuralgic pains from which he suffered, along the nerves, whose course he well knew. He was then hopeful, and his natural cheerfulness was unabated. It is difficult to imagine that the bright, keen intelligence, so alive to all that pertains to progress in knowledge,

and to the welfare of humanity, is now beyond us; but his memory will long remain in Glasgow, and in the hearts of thousands of his pupils. He died full of years and of honour; and it is a satisfaction to think that, after a long and busy life, he had a few years of peaceful retirement, listening to the innocent prattle of his grandchildren, and enjoying in London the society of kindred scientific spirits.

Dr. Thomson left a widow, the daughter of Mr. Ninian Hill, Writer to the Signet, Edinburgh, and an only son, Mr. John Millar Thomson, Lecturer on Chemistry in King's College, London, and one of the Secretaries to the Chemical Society. On his retirement in 1877, his portrait, painted by the late Sir Daniel Macnee, was presented to the University, and now hangs in the Hunterian Museum. Although wanting the classical refinement of expression characteristic of Dr. Allen Thomson, it is on the whole a good likeness, and will hand down the well-known form and features to future generations.*

In one of his last visits to Glasgow he wrote in an album a few well-known lines which, I think, so fully represent his philosophy and give us the secret of his successful and happy life, that I shall quote them in bidding our friend farewell.

"It's no in titles nor in rank;
It's no in wealth like Lon'on bank,
To purchase peace and rest;
It's no in makin' muckle mair:
It's no in books, it's no in lear,
To make us truly blest:
If happiness hae not her seat
And centre in the breast,
We may be wise, or rich, or great,
But never can be blest."

John G. M'Kendrick.

*An account of his last illness is given in the "Lancet" of 12th April, 1884.

LIST OF ALLEN THOMSON'S WRITINGS.

1. On the Development of the Vascular System in the Fœtus of Vertebrate Animals. Graduation Thesis. Edinburgh New Philosophical Journal, Vol. ix., 1830, p. 295, and Vol. x., p. 88, and p. 251. Abstract in Edinburgh Medical Journal, Vol. xxxvi., 1831, p. 209.

2. A Probationary Essay on the Formation of New Blood Vessels, on the occasion of becoming F.R.C.S.E., in 1832.

3. Accounts of some New Experiments on the Sensibility of the Skin, by Dr. Weber, Professor of Anatomy at Leipsig. Edinburgh Medical Journal, Vol. xl., 1833, p. 83.

4. Contributions to the History of the Structure of the Human Ovum and Embryo before the third week after conception, with a description of some early Ova. Edinburgh Medical and Surgical Journal, Vol. lii., 1839. p. 119.

5. On the origin of Double Monsters. Edinburgh Monthly Journal of Medical Science, 1844.

6. A description of congenital malformation of the auricle and external meatus of both sides in three persons, with experiments on the state of hearing in them, and remarks on the mode of hearing by conduction through the hard parts of the head in general. Proceedings of Royal Society of Edinburgh, 1845.

7. On the Co-existence of Ovigerous and Spermatic Capsules on the same individuals of the Hydra Viridis. Edinburgh New Philosophical Journal, Vol. xlii., 1846-7, p. 281.

8. Outlines of Physiology, for the use of students. 12mo, pp. 308. 1848.

9. On the structure of the Glands of the Alimentary Canal. Annals of Anatomy and Physiology, by John Goodsir, p. 33. 1850.

10. Notice of the Dissection of a case of Lateral Transplantation of the Viscera of the Thorax and Abdomen in a man. Glasgow Medical Journal, Vol. i., 1854, p. 216.

11. Remarks on the Comparison of the Ovarian Ovum of Birds and Mammiferous Animals. Edinburgh Monthly Journal of Medical Science, 1855, p. 97.

12. Notice of recent Researches on the origin of Entozoa, more especially of Tape Worms. Glasgow Medical Journal, Vol. iii., 1856, p. 178.

13. On the formation and structure of the Spermatozoa in Ascaris mystax. Reports of British Association, 1855, p. 138.

14. On the Brain of Troglodytes niger. Reports of British Association, 1855, p. 139.

15. Contributions to the History of Fecundation in different Animals. Reports of British Association, 1855, p. 139.

16. On unusual Mobility of the Iris, his own case, by John Paxton, M.D., Kilmarnock, with remarks by Dr. Allen Thomson, in a letter to the Editor. Glasgow Medical Journal, Vol. iv., 1857, p. 451.

17. Further remarks on Dr. Paxton's case, with observations on the Structure and Action of the Parts concerned in the Focal Adjustment of the Eye. Glasgow Medical Journal, Vol. iv., 1857, p. 456.

18. On the Phenomena and Mechanism of the Focal Adjustment of the Eye to Distinct Vision at different distances. Glasgow Medical Journal, Vol. v., 1858, p. 50.

19. Notice of the case of Mons. E. Groux, in which a congenital fissure of the Sternum exposes partially to observation some of the movements of the organs of the circulation. Glasgow Medical Journal, Vol. vi., 1859, p. 48.

20. Biographical Account of his Father, Dr. John Thomson, prefixed to the Second Edition of John Thomson's Life of William Cullen, Edinburgh, 1859 (the First Edition of Thomson's Life of Cullen was published in 1832); here also is a short Biography of his brother Dr. William Thomson, Professor of Medicine in Glasgow.

21. On the Spinal Cord and Nerves. Proceedings of Philosophical Society of Glasgow, 1860.

22. Description of the Dissection of a case of Right Aortic Arch, with Remarks on this and allied Malformations. Glasgow Medical Journal, Vol. xi., 1863, p. 1.

23. On the Difference in the Mode of Ossification of the First and other Metacarpal and Metatarsal Bones. Journal of Anatomy and Physiology, Vol. iii., 1869, p. 131. An Abstract of this Paper appeared in the Glasgow Medical Journal, Vol. i., New Series, 1869, p. 202.

24. Address to the Biological Section of the British Association, 1871.

25. Address as President of the British Association—Report of Forty-seventh Meeting—Plymouth Meeting—1878, p. 68.

26. Contributions to Todd's Cyclopædia of Anatomy and Physiology. Vol. i., Circulation, 1835-1836. Vol. ii., Generation, 1836-1839. Supplementary Volume, Ovum, 1859.

27. Seventh Edition of Quain's Anatomy, along with Professor Sharpey and Professor Cleland, 1867.

28. Eighth Edition of Quain's Anatomy, along with Professor Sharpey and Mr. E. A. Schäfer, 1876.

29. Ninth Edition of Quain's Anatomy, along with Professor E. A. Schäfer and Professor G. D. Thane, 1882. The portion on Embryology, Vol. ii., pp. 731-911, wholly written by Dr. Thomson.

30. Report by the Chairman of the University Removal Committee—University of Glasgow New Buildings, Glasgow, 1877.

31. Article "Embryology," in Ninth Edition of Encyclopædia Britannica, 1878.

32. Article "Ovum," in Ninth Edition of Encyclopædia Britannica, 1884.

XIII.—*Note on Modern Forms of the Microscope.* By William Limont, M.A., M.B.

[Read before the Society, 19th March, 1884.]

Class or "students'" microscopes are necessary for at least teaching purposes. On the whole, those made by the best English makers are now better and cheaper than Continental instruments. When it can possibly be afforded, an English skeleton microscope, on the American (Jackson-Zentmayer) model, should be got by students and others. These microscopes are not very costly, and if made in quantity, and of a fixed standard size, could be sold at a much lower rate. They take *both* English and Continental accessories, unlike the microscopes of Continental makers. As they are made to allow instant removal and replacement of stage and sub-stage, they can be bought with any form of plain stage, and without sub-stage, or with a sub-stage to carry an improvised condenser. This allows of the subsequent addition of the very best mechanical and other stages, and of all sub-stage apparatus. They have the swinging sub-stage, which has many advantages, and enables one at least to postpone the purchase of certain expensive articles. As to objectives, English dry objectives are now often cheaper than those of the best foreign houses, and they are made in much greater variety. The same remarks apply to oil immersions, with the addition that those of Powell and Lealand are certainly superior to any yet made on the Continent. The English and American oil immersions have the highest apertures, and are therefore to be preferred, for we have not settled upon the apertures best for our work, and a high aperture can at any time be cut down by a temporary posterior diaphragm, while a low aperture cannot be raised.

The superiority of the workmanship laid out upon English first-class microscopes is beyond doubt. In no case is it a good investment to buy a foreign first-class instrument, and in most cases a first-class English "skeleton" microscope should be got, in preference to a third-class microscope, either English or foreign.

XIV.—*On some of the chief features of the Physical Geography, including the Geology, of China, and the bearing thereof on the future of that Empire.* By Rev. ALEXANDER WILLIAMSON, B.A., LL.D., Glas., Author of "Journeys in North China," &c., &c.

[Read before the Society, 5th March, 1884.]

CHINA proper extends from about lat. 20° N. to lat. 42° N., and from long. 102° E. to long. 124° E., or about 1,474 miles north and south, and 1,355 miles across, forming a compact block of country with a coast line of 2,500 miles, and including the islands of Formosa and Hainan, comprising 1,539,930 square miles. If we add to this the dependencies of China we have an area of country comprising 4,561,525 square miles, or more than one hundred and fifty times larger than broad Scotland with her 186 islands combined.

To treat the Physical Geography of such a country within the compass of an hour is not an easy task. It is like trying to pack Ben Lomond into a snuff-box, or some such feat. Still, by care and condensation, I hope to give you some little idea of the country, and may perhaps start topics of interest which you may pursue in your private studies.

One of the first things which strikes an observer acquainted with both countries, when he enters on a consideration of the Physical Geography of China, is the resemblance which that Empire bears to the north-eastern portion of the Continent of America. Both lie on the eastern side of a great continent, in both the chief mountain ranges run N.E. by S.W.; both have a gulf stream flowing northward parallel to their coasts, which in neither case, however, affects the climate; both are powerfully affected by the influence of the arctic regions; both have a very cold winter, with an equally hot summer; the minerals of each are alike, so also is the produce of the fields and orchards: for they have each exchanged cereals and fruits with mutual advantage. In fact, the contour of the country—hills, rocks, ravines, and streams, the waving crops,

the laden orchards, the dry bracing air—are so alike, that, were it not for the human surroundings, a visitor from Maine or Massachusetts could hardly believe that he had left his native country. And if we extend our observations to Canada, the resemblance not only continues, but is heightened. Like the Amoor, the St. Lawrence pursues a N.E. course before it falls into the sea; Kamschatka represents Labrador; Saghalien, Prince Edward Island; and Corea, though much further south, and with a much more salubrious climate, may be likened to Nova Scotia. The great mountain ranges of China may be compared, in direction and character and height, with the Alleghanies of the U.S.A., and the Watchish mountains of Labrador; and as the Appalachian ranges have determined the outline of Eastern America, so the ranges of which we speak have determined the eastern coast of China. The parallels of latitude of the great cities in a measure correspond, though the Chinese are somewhat more northerly than the U.S.A., *e.g.*, Moukden 42° N., Boston 40°, Peking 40° N., Washington 39°, Shanghai 32° N., New Orleans 30°, but China reaches much further south than the U.S.A., by about ten degrees.

The next marked feature in the physical structure of China is the system of parallelism, which prevails in a very special manner. Pumpelly was the first to point this out. He showed that a straight line drawn through the longer axis of the Gulf of Pechili and prolonged south-west would be found to coincide with the centre of the Delta Plain in Shantung, the low lands in the western portion of Hunan and Hupeh, and the valley of the river Yang-tse Kiang as it flows through Sz-Chwen and Yunnan; also, if extended north-east, would follow the valley of the Liao river in Manchuria and the bed of the lower Amoor river, on to the Arctic Regions. With this as a central line, minor lines coincide—(1) On the west we have one commencing east of Kalgan and proceeding down through the centre of Shan-si and the valley of Ching-too in Sz-Chwen; and further west we have the plain commencing on the east of the Ortoos country and extending through a portion of Shen-si and part of Kan-suh. Again (2), on the east side of this line we have the same peculiarities. Here we find the coal basins of Hunan, the Tung-ting lake, the valleys of several important rivers, such as the Yuen and the Tz—the low lands around Hankow, and the valley of the Hoai, in the province of Ngan-Whui. Further east we have another great basin, parallel to the others, viz.:—that which is found in Kiang-si, the eastern half of Ngan-Whui, and

the coal-fields of Chih-Kiang and Kiang-soo. The same marked features prevail outside of China in the Chinese seas, where we have the basin extending between the mainland and Formosa, up in the centre of the sea, bounded on the east by the islands of Japan, the Kurile Islands, and the Aleutian Islands.

While these basins and mountain ranges are thus very clearly indicated, we have another set of elevations, trending east and west; and to them is due not a little of the beneficial configuration of the Empire. The most northern of these rises on the plateau of Central Asia, or rather appears to be a continuation of the Kwen-lun mountains, and proceeds eastward, dividing into two marked ranges, the northerly passing through the south of Shen-si and Honan, and reappearing in the centre of Shantung. This range is called the Foo-nieu-shan, and consists of a series of parallel mountains, ranging from 4,000 to 5,000 feet above sea-level, and consisting chiefly of metamorphic formations and granite. The other range, diverging southwards, then running nearly parallel to the former, is called the Tsing-ling-shan. The summits rise from 5,000 to 11,000 feet above the level of the sea. This range is distinguished by embracing five parallel belts of diverse character; the first, a granite belt, the peaks of which rise very high, covered with trees on its northern slopes; the second consists of very ancient green schists overlaid by silurian strata, the same schists as those found on the Wu-tai-shan in Shan-si; the third belt is made up for the most part of limestone; the fourth consists of limestone now changed into marble, and interspersed by masses of granite; while the fifth belt is composed chiefly of silurian strata interspersed by small granite veins, and converted into mica-schist, gneiss, marble, and quartzite.*

The other great range lying east and west, which also is a projection from the table-land of Central Asia—or rather, as I think, a continuation of the Himalaya mountains—runs through on the south of Sz-Chwen, the centre of Kwhei-chow, and continues on the north of Kwang-si and Kwang-tung to the sea. These huge east and west spurs, all sloping towards the sea, first of all give the preponderating eastwardly direction to all the great rivers of China. But, secondly, they do more; they wonderfully tend to distribute the rain-fall, for they originate

* See Baron von Richtofen's letters in the Shanghai Chamber of Commerce.

numerous streams and rivers of greater or lesser volume, which flow, in the main, north and south, while the other ranges give off rivers with a north-west and south-east flow, and thus serve to water the country plentifully in all directions.

The Physical Geography of Southern China and the Indo-Chinese Peninsula harmonize with the foregoing views. The greatest authority on this matter, Richtofen, informs us that the province of Yunnan consists of a plateau averaging between 5,000 and 6,000 feet above the level of the sea, and projects spur-like in a south-westerly direction. From Yunnan the elongated ridges of the Indo-Chinese Peninsula—the lands of Burmah, Siam, Cochin China, and the Shan country—stretch southward as the fingers from the palm of the hand; and from this region five mighty rivers escape, viz.:—(1) the Yang-tse Kiang, taking a north-easterly course; (2) the Salween, flowing south and west, and debouching at Maulmein; (3) the Mekong, also wending south, and reaching the Chinese sea on east coast near Saigon; (4) the Si-Kiang, originating near the capital of Yunnan, flowing nearly due east to Canton; (5) while the fifth, the Song Koi or Red river, flows south-east to Hanoi and the gulf of Tong King.

From what I have said you will perceive that the greater portion of the surface of China is remarkably diversified; and, excepting portions of the alluvial plain, the traveller is never very far from some mountain range or other, thus possessing hill and dale and stream and lake, imparting fertility, health, variety, and beauty to the country. Every here and there, especially in north and west of China, you have glimpses of beautiful scenery, reminding you of parts of the south of England, and even of the glens of Scotland, suggesting those matchless lines—

"Whyles ower a linn the burnie plays,
Or through a glen it wimpl't;
Whyles round a rocky scaur it strays,
Whyles in a weil it dimpl't—
Whyles glittered to the mighty rays
Wi' bickerin, dancing, dazzle;
Whyles cookit underneath the braes
Below the spreading hazel;" &c., &c.

And the "whirr" of the pheasant, the cry of the partridge, the erect ears of the timid hare, the bushy tail of the fox, the flight of the deer heighten the enchantment, while the glare of the wolf, the growl of the bear, or foot-prints of the tiger tell us we are far from bonnie Scotland.

Means of Intercommunication.

(1) *The Waterways.*—The great rivers of China are three in number. The first in every respect is the Yang-tse Kiang. This grand river rises about lat. 35° N., long. 90° E., on the southern slopes of the Kwen-lun mountains, and runs in that great valley, or rather "depression" (for it is full of mountains), which lies between these mountains and the Himalayas, then it turns southward through Tibet till it reaches Sz-Chwen, when it takes a northward course, and then flows, as a rule, north-easterly to the sea. It has a course of not less than 2,900 miles, and drains an area of 650,000 square miles, or three times the area of France. This great river is navigable for the largest steamers to Hankow, 600 miles from the sea—for smaller steamers to I-Chang, 400 miles farther from the sea. Here begin those tremendous gorges and rapids, three in number, 16, 32, and 62 miles respectively from I-Chang, which are so famous—but which would afford no great impediment to stern-wheel steamers made for the purpose—and in this case steam communication could proceed as far as Chung-King Foo, 1,364 miles from the sea. Beyond this the river continues deep and navigable, and communication by steam launches could be carried on from 300 to 400 miles farther inland. Native boats go easily at all seasons as far as Ping-Shan-Hien, say lat. 27° N., and long. 104° E., or 400 miles above Chung-King. Here you meet rapids so strong that few boats can overcome them ; but by changing into smaller boats, or taking a short land journey, you can have water communication much farther into the interior.

One of the most important features of this great river is the number of large navigable affluents which emerge from the country in all directions, and so give a most marvellous facility for intercommunication. To mention only the chief. On the right bank, proceeding seawards, you have the Kien-Kiang, which is navigable 170 miles, and communicates with the capital and province of Kwei-Chow, and enters at the city of Foo-Chow; the Yuen-Kiang, which flows through the east of Hunan, enters the Tung-Ting lake, and then communicates with the Yang-tse-Kiang ; the third is the Siang-Kiang, the head waters of which mingle with the head waters of the Si-Kiang, which flows to Canton; then we have the Lei-Kiang, a branch of the former, also communicating with the south and Canton by the Che-ling pass ; the Kan-Kiang, which approaches the Me-ling pass, and which, flowing through

the province of Kiang-si, empties into the Po-yang lake, and thus joins the Yang-tse Kiang at Kiu-Kiang; and, lastly, the Whang-Poa, which, communicating with the Tai-hoo lake, joins the Yang-tse Kiang, *via* Shanghai, at Woo-sung. On the left bank we have three large rivers, which afford water communication in all directions through the splendid province of Sz-chwen, viz.:—the Min-Kiang, the To-Kiang, or Foo-Sung-Kiang, and the Kia-long-Kiang, or Tsien-Kiang, which join the Yang-tse at the emporiums Soo-chow-foo, Loo-chow, and Chung-King-foo respectively; then we have that most important river the Han-Kiang, which enters the Yang-tse Kiang at Hankow or mouth of the Han, and which gives us water communication through Hupeh, and into Shensi and the north-west provinces; and much further east we have the Grand Canal at Chin-Kiang, which gives us a waterway through three provinces, viz.:—Kiang-soo, Shantung, Chih-li, and on to Peking. The Yang-tse Kiang discharges, on an average, 770,000 cubic feet of water per second, or an annual average of sediment to the amount of 6,428,858,255 cubic feet, or almost 200 cubic feet of soil per second.*

The second is the Yellow river. This river rises in a very interesting region. The Chinese call it "the star and constellation lake," from the innumerable fountains, great and small, which bubble up, sparkle into light, and together form the origin of the Yellow river—which of course means that, like the Lualaba in Africa, it has its source in a lacustrine district. This district lies about lat. 34° N., long. 98° E., and is on the northern slopes of the Kwen-lun, as the source of the Yang-tse Kiang is on the southern. The course of this river is first north-east, then it makes a huge bend, flows south-west down the next parallel till it comes to Honan, when it takes an easterly direction. I have crossed it at many points, and know it well. It is a tantalizing river in almost every view of it—at some places full, deep, and rapid, at other places broad, shallow, sluggish, and full of sandbanks; at some places navigable for good-sized boats, at others only fit for rafts. Since B.C. 600 it has changed its lower course no fewer than nine times over four degrees of latitude. At present it debouches at the north-west corner of Shantung, at a place called Tieh-mun-Kow, and is navigable for small steamers from the mouth up to Tsi-nan-foo, the capital of the province, and for say 50 or 60 miles beyond. The

* See *Nature*, Vol. XXII., p. 486.

mouth has recently been dredged, and at low-water has ten feet on the bar. All the heavy machinery for the Shantung arsenal was brought up on it.

It has a course of 2,600 miles, though only 1,200 in an air line, and is subject to tremendous floods, so that it is called by the natives "China's Sorrow." Sir G. Staunton estimated the sediment at 17,520,000,000 cubic feet per annum. Mr. Kingsnull gives three-fourths of this, but I think the quantity is much less than even that—not much over one-half.

The third great river is the Si-Kiang or West river, which rises in Yunnan, flows eastward, and debouches at Canton. The first 130 miles from the sea it has 15 feet of water; 75 miles farther to Woochow it is fit for light craft, and altogether it is navigable for 600 miles by good-sized boats. Owing to its greater volume of water and greater freedom from pirates, it will always compete with the Song-Koi or Red river, which passes through Tong-king, in regard to the commerce of that rich province. It has two important affluents, both on its left bank—viz., one which flows from Kwe-lin-foo, at the north-east corner of Kwang-si, where its waters connect with the head waters of the Siang-Kiang mentioned above, and so provides uninterrupted water carriage between the whole of the north and south of China—a fact, the economical importance of which cannot be over-estimated. The second is the Po-Kiang or North river, which is deep, and navigable for steamers to Shoo-chong, at which place it bifurcates, one affluent flowing north-west, and reaching the Che-ling Pass, which is only about 1,000 feet above the sea, and where there is only 30 miles of porterage between it and another tributary, which also enters the Siang-Kiang, and so this river provides a second water route to the north, *via* the Tung-Ting lake. The other branch flows north-east, and proceeds to the foot of the Mei-ling Pass, on the other side of which there is the Kan-Kiang, which flows into the Po-Yang lake, thence into the Yang-tse Kiang, and north. This Pass is famous as that through which Lord Amherst's Embassy passed on its way to Peking. There are thus three communications between North and South China—one navigable throughout.

Then we have the Pei-ho or Tien-tsin river, of no slight importance, impinging on the Grand Canal, and approaching Peking, and carrying on an average 7·755 cubic inches water per second, and about 80,000,000 cubic feet of soil annually into the sea. Also the Yaloo-Kiang, which flows between Manchuria and Corea,

which, with its magnificent timber, coal formations, and iron ore, promises to be the Tyne or the Clyde of China. We have also innumerable rivers and streams on the eastern coast, some—like the Min or Foochow river—of considerable commercial importance; and others of lesser value, rising on the sides of the eastern ranges, and flowing into Formosa Channel and China Seas.

In addition to these rivers, we have in Manchuria the Liau-ho, which flows through a large portion of Central Manchuria, the Huh-loong-Kiang and Usuri, which drain Northern Manchuria and enter that great river the Amoor, which debouches in the Northern Sea.

The great plains of India not only receive the rain-fall on the southern slopes of the Himalayas, gathered and distributed by that great river the Ganges, but also, by a very striking arrangement, the rain-fall and melted snows of the northern slopes. The great river which gives its name to the whole country, the Indus, takes its origin on the northern side, flows first westward, and afterwards, by a most unexpected cleavage in the rocks, passes through that high precipitous and magnificent range, and pours its waters over North-western India. In like manner, the Brahmapootra issues not far from the source of the Indus, but flows eastward, then south-east, likewise passes through gorges in the Himalayas, and provides for the fertility and water carriage of the North-eastern Provinces. So, also, with the chief rivers of China. As we have seen, the Yang-tse Kiang rises on the southern side of the second great range of Asia, viz., the Kwen-lun mountains—not much behind the Himalayas in rugged grandeur—while the Yellow river takes its departure from the northern slopes, and thus the entire rain-fall of this immense range is most effectually utilized for the benefit of China. We all know about the grandeur of the rifts through which the Indus dashes in its beneficent course. The rents in the mountain range through which the Yang-tse Kiang passes are grander still. The vertical continuous trench is commonly from 2,500 to 4,000 feet above the level of the river, sometimes 6,000.

Without these Titanic rifts—at the precise place and direction in the mountain range on the North of India—Bombay and North-east India would have been complete deserts. So, in like manner, without this uninterrupted cleavage in Sz-Chwen, starting at the particular point and continuing uninterrupted, there would have been no Yang-tse Kiang. Without the Yang-tse Kiang there would

have been no China as we have it. Call these things the freaks of nature if you please, I call them the prescient acts of a beneficent Creator making provision for the great empires of the east. St. Rollox stalk is 435 feet high. Imagine, therefore, the force necessary to rend asunder such great rocks, giving us more than 100 miles of walls of solid limestone from eight to ten times the height of that towering object. In the same manner, though less striking, has a passage been provided for the Yellow river; and also for the water communication between north and south of China.

Living in our island home, we little appreciate the value of great rivers in the economy of nations. We are apt to contemplate them merely as sources of water power for our machinery, or a theatre for the amusement of the angler, or as imparting variety and beauty to the landscape. But I need hardly say that their uses are far wider and more important than these. The priests of Egypt said to Herodotus that "their country was the gift of the Nile," a phrase as elegant as it is comprehensive; the great plains of India are also as truly the gift of the Ganges, the Brahmapootra, the Indus, and other rivers; so also the great delta plain of Central China—700 miles long by 150 to 500 miles broad, an empire in itself—is the gift of her rivers.

But these rivers not only have produced that great district—they and their innumerable tributaries are unweariedly carrying enormous burdens of silt from the table-lands of Eastern Asia, which they deposit partly along their courses, but chiefly at their mouths, thus creating new soil, extending the boundaries of the country, and forming new islands for the habitation and support of men—thousands of square acres every year. Nor is this all; they are the servants of man, or rather the almoners of Providence; they are the great sources of fertility—they not only irrigate, but they manure. The husbandman taps their banks with his canals wide and narrow, deep and shallow; and I have stood and wondered at the water, as the farmer with his foot opened the cutting, rushing into the prepared trench laughing and dancing, as if exulting to respond to the help of man—filling his trenches, and covering his fields not only with grateful water, but with a layer of loam, which forms the best of manures. Thus these rivers multiply the produce of the country. Again, they afford safe and cheap means of transport, for water carriage is from 20 to 40 times cheaper than land carriage. On their bosoms they carry not only the rude craft of the countryman,

and the barge of the traveller, but the heavy laden boats of the merchant; and in the present day afford scope for those huge steam leviathans which are both the wonder and the blessing of Central China. Further, they provide the natives with an abundant and unfailing supply of food in the article of fish—varied, wholesome, and cheap; and the late International Fisheries Exhibition shows how well they can take advantage of it.

In view of the benefits which the inhabitants derive from these rivers, and the mystery connected with their rise and fall—fullest at the driest season, sometimes rising as many as 50 feet above their ordinary level, providing moisture, water, and manure when they are most needed, just after the seeds are sown in the earth, and all through the hot summer season, when growth is most rapid—who wonders at the ignorant natives falling down and worshipping them? And who among us, looking at the varied uses of our mountain ranges—the gradations of elevation, direction, and consequent slow and gradual distribution of their watery wealth—does not lift up his heart in gratitude to Him who formed the mountains and set the hills in their places. And, in the city of Sir William Thomson, may I be permitted a little flight of imagination, and suppose that in the future these rivers may add yet another boon to their numerous uses, namely, that their rapids and falls may afford the chief source of light to China, drive the machinery of the country, and even more extensively increase the fertility of the soil?

But these rivers, like every other good, have their evil side if neglected. Sources of the most incalculable blessing, they are also sometimes scourges of tremendous description. Unless their banks are carefully attended to, and their surplus water drained off, they overflow, and submerge, mercilessly, fields and hamlets and towns, and carry devastation often over tens of thousands of square acres. And the desolation is often of the most appalling kind: for, bearers of fertility in their normal course, in flood they are unmitigated curses, inasmuch as the rapidity of the current carries in its resistless whirl the heavy sand which in their slow course is usually deposited at the foot of the mountains, and thus, instead of the generous loam, they spread this most unfertile of all soil over the country. Thus they not only sometimes sweep the country clean of its towns, hamlets, dwellings, stock, and inhabitants, but in large districts present such as return with a barren, sandy, stony waste, which it takes years to reclaim.

(2) *The Lakes.*—The numerous lakes also form an important element in the waterways of China. They lie chiefly in the parallel basins to which I have referred; and form not only links, but rather natural reservoirs, and so regulate in a measure the gradual diffusion of the waters of the country. The chief is the Tung-Ting lake, in Hunan, 225 miles in circumference; the second, the Po-Yang lake, in Kiang-si, 90 miles in length, by 20 in breadth; the third, the Tai-Hoo or Great lake, on the borders of Kiang-soo and Cheh-Kiang, 150 miles in circumference, dotted over with islands, where the luxurious inhabitants of Hang-Chow and Soo-Chow delight to rusticate. There are several smaller lakes on the north of Kiang-soo; and three in Yunnan, one, 40 miles long, communicating with the Yang-tse Kiang by the Poo-too river.

But these facts, striking though they are, give a very inadequate idea of the wonderful water communication in China. Industry, ingenuity, and perseverance have lent their aid to nature. Artificial canals of all descriptions, long and short, wide and narrow, deep and shallow, have been dug wherever practicable, in all directions, linking rivers, joining smaller streams, connecting lakes, or forming links among themselves—a perfect and beautiful net-work—with their high, and often wide, but always elegant bridges. In Central China there is hardly a town of any importance, and no city, as far as I know, which is not tapped by one or more in this lace-work of waterways—a tremendous benefit to commerce. The greatest among all these artificial waterways is the Grand Canal, commenced early in the Christian era, and completed by Kub-lai Khan, 1295 A.D. This extends from Peking to Hang-Chow, crosses both the Yellow river and the Yang-tse-Kiang; its length is about 708 miles. Even in its present condition it is of immense importance to the country; but, by a comparatively little outlay, could be made of incalculable strategical, as well as commercial, value to the empire.

(3) *The Highways.*—As in old Rome, which had its famous highways, beginning at the Forum, and extending in all directions through the provinces, to the very confines of the empire—to Persia in the east, and Gaul and Britain in the west—so in China we have like roads, laboriously and carefully constructed, starting from the Imperial Palace, and radiating in all directions, somewhat out of repair at present, but still usable for all sorts of traffic. And just as the western Empress of the world established stages and relays for the rapid conveyance of travellers and despatches,

so in China we have a like system, but much more elaborate than in the Roman empire. And not only so, but we have what the Romans lacked, a system of telegraphy over the greater part of the country. High mounds, erected on the peaks of conspicuous hills all over the coast, at convenient distances from each other; towers built on the highways leading to the capital, at 10 li, or 3⅓ miles, apart, all these provided with materials for signalling, *e.g.*, firewood for night, and wolf's dung for daytime—which is said to emit a smoke dense and dark, and which ascends less affected by wind than the smoke of other materials.

The Soil.

The soil of China may be divided generally, but with great accuracy, into four different kinds. First, we have the common loam, which may be called the product of civilisation, viz., the result of the felling of primeval forests, of agriculture, drainage, and irrigation, continued through many centuries, and which prevails all over Southern and South-eastern China; second, we have the immense alluvial plain of Central China, to which I have referred, of extraordinary fertility and variety of products; third, we have the great "red basin," as it has been called, which occupies the greater part of the immense province of Sz-Chwen. The soil here is a kind of red clay, and is formed by the decomposition of clayey sandstones of that colour, and is of enormous development. By itself this soil would not be productive to any marked degree, but, owing to the great moisture of the climate—the hilly character of the country, the immense number of brooks, streams, and rivers of Sz-Chwen, the consequent natural irrigation, and the ingenuity of the inhabitants, the fertility of Sz-Chwen and the variety of its products are unparalleled in China. Every hillside is terraced, even at very acute angles, and irrigation works are cut parallel to each other, at various heights, down to the foot. Thus the utmost is made of the water—not a particle is lost. The centre of this "red basin" lies in the middle of the province, and is called the plain of Chin-tu-foo, and is 1,600 to 1,800 feet above the level of the sea. But this valley is a small kingdom in itself, containing 2,400 square miles, and sustaining a population of at least 3,600,000. The fourth description of soil is the loess. It presents by far the most peculiar feature in the soil of China. It is found as far

north as the country of the Ortoos, at the upper bend of the Yellow river; and constitutes the chief portion of the soil of four provinces, viz., Kan-su, Shen-si, Shan-si, and Honan. It also overlies large districts in Chih-li and Shantung, reaches as far east as Manchuria, and as far south as the Tung-ting and Po-Yang lakes, but here all traces of it disappear—thus covering an area of not less than 250,000 square miles. It smoothes the contour of the country, rounds the corners of the hills, and with its wavy outline looks, as respects shape and form, as if some prodigious snow-storm from the north-west had swept across the provinces, and left its burden on their slopes. It constitutes also an important element in the Physical Geography of North China. It is to be found at all elevations, reaching from a few hundred feet above the level of the sea, as in parts of Shantung and Honan, up to 6,000, in Shan-si, and is even found, on the upper slopes of the Wu-tai-shan, no less than 8,000 feet above the sea line. It also, of course, varies in thickness, from a few score of feet up to 1,000 or 1,200 feet in vertical thickness. It consists of a kind of hard but friable earth, of yellow colour, extremely porous and tubular in structure, these tubes often ramifying, like the roots of plants, and frequently lined with a film of lime. Analysed, it contains carbonate of lime, fine sand and pure loam. It is not stratified, but cleaves vertically, often in huge rents. It contains fossil land, —shells, bones of quadrupeds, sometimes so many as to be used for manure; and portions of it are mixed here and there with local gravel, but this is only near the foot of mountains.

This loess is remarkable in a great many ways. (1) It is of extraordinary fertility. It requires no manure, a little rain is all that is needed, and the crops surpass all other soils. (2) Portions of it, carried by streams or floods, and spread over the lower levels, act as manure, and produce crops which otherwise would be impossible. Here we see a marked difference between the fertility and recuperative power of North and South China. In South China the area of cultivation is limited, for the most part, by the amount of manure which can be supplied, or in other places by the elevation to which irrigation can be extended; but on the loess there is no need for manure; and while in the South, irrigation never rises higher than say 2,000 feet, in the North the hills can be cultivated to any height as far as the loess prevails, so that excellent crops are constantly gathered from hill sides, up as far often as 4,000 to 6,000 feet above the sea.

Baron von Richtofen says this fertility results (1) from the porous character of the loess, which absorbs from the air carbonic acid and ammonia; and (2) from the fact that rain, descending deep into the vertical cleavages of the loess, meets the humidity contained in the lower portions, and by the well-known law of diffusion of liquids, imparts moisture to the vegetation on the surface. Be this as it may, the provision is wonderful.

But the loess not only affords food, but shelter for the inhabitants. They excavate houses in its sides, beautiful and commodious houses, often ranging up to two or three and more stories, and not isolated houses only, but villages and towns—constituting one of the most extraordinary sights a traveller can witness—not tiers of swallows nests, but tiers of human habitations one above the other, up to which they go by ladders or ropes. And these houses have the great advantage of being not only warm in winter, but cool in the summer.

It is interesting to notice in this connection, that at the very dawn of their history, we find this soil described in their classics most accurately, and its fertility acknowledged. It is stated to be "yellow and mealy or mellow," and "the revenue the first of the highest class."

As regards the formation of the loess, authorities are not yet agreed. Pumpelly maintained it was lake deposit. Richthofen refutes this, and assigns "winds" as the cause, and says it is a "sub-areal formation." My own opinion is, that "winds" are causes totally inadequate; and I am inclined to look upon it as another important argument in favour of the Duke of Argyle's theory: for I can see no other way by which all the peculiarities of the case can be met than by the submergence of the soil, and a great flood flowing south-east over that portion of the world, and carrying with it the dunes and sands of Central Asia. And the fossil land-shells found in it, and organic remains of the mastodon, red deer, &c., and such things, add still greater strength to this theory.

But while China has thus four very marked varieties of soil, it possesses an almost infinite number of sub-varieties—pure, mixed, and intermixed. Entering several degrees within the tropics, and extending to the Amoor, possessing every degree of temperature, every proportion of altitude from the sea level, to the line of perpetual snow, adorned by every description of scenery, hill, dale, woodland, and stream, with every measure of sunshine and shade, I believe there is no plant or tree which grows in any part of the world but would

find a congenial habitation in some part or other of China, and *vice versa:* for neither Fortune's "wanderings" and the treasures he gathered, and wherewith we have beautified our greenhouses, and adorned our gardens, nor the discoveries of yet more recent botanists, have by any means exhausted the edible, economical, and ornamental plants, herbs, flowers, and shrubs with which China is prepared to enrich the west.

Under this division it may be well to refer to the soil of the outlying countries in close proximity, which are dependent on China, such as Manchuria, 362,313 square miles, population 12,000,000; Mongolia, 1,288,035 square miles, population 2,000,000. These vast tracts are gradually being brought under cultivation by the Chinese. They afford immense scope for the overflow of the population of North China, and will ultimately form most important fields of food supply for the whole of China proper. As yet, only Southern Manchuria has been brought in any measure under cultivation—the greater portion of Central Manchuria and the whole of Northern Manchuria are still occupied by huge forests, great fertile valleys, fine rivers, and, in the extreme west, by extensive plains, analogous to Canada, and possessing a climate similar to the Dominion. Mongolia, having an area not much less than China proper, is simply one vast undulating prairie, in many places producing huge crops of tall native prairie grass—the result of the top-dressing of lava, with its rich constituents—thus giving indications of the fertility of the soil, which would, of course, produce wheat, millet, and other cereals in equal luxuriance. In addition to these, I need not refer to Tong-King, Cochin-China, and the rich islands on the coast and in the Pacific. All these are now occupied, in a greater or lesser degree, by colonies of Chinese, so that there is hardly a diminutive islet visited by our naturalists where the Chinese are not found, all of whom are simply pioneer lines of ants, working for, and sending supplies to, their mother empire. There need therefore be no apprehension of the scarcity of food for China.

The Meteorology of China.

As with the soil, so with the climate, we have every imaginable diversity. But the meteorology of China has not yet been so carefully or scientifically investigated as is desirable. Many observers, however, are now at work. Through the exertions of

Sir Robert Hart—who is always alive to whatever will conduce to the best interests of the empire—sets of instruments have been provided for all the lighthouses recently built, and in course of erection, over the extended coast of China; also the officers of the various custom-houses at the ports have likewise received sets of instruments. Further, an observatory has been established at the Roman Catholic establishment near Shanghai, under the direction of a Roman Catholic priest. This observatory is in telegraphic communication with all parts of China and the East, and has already proved itself of immense value in every way, and especially by its forecasts of typhoons. Meantime, I may say in general that as we have every conceivable variety of soil, so we have every possible diversity of climate—tropical heat in the south, a temperate zone in the centre, fine bracing weather and clear frosty winters in the north, and, in fact, a place—in some corner of the empire—suitable for any constitution.

Products of the Soil.

Food Products.—Chief among these stands (1) rice, of which there are many varieties. The kind in general use all over the south and centre of China is the common variety; but in the north we have a species which is not very well known outside of China, and which is worthy of some attention. I refer to the dry soil rice. It is sown in spring, on ordinary soil, like wheat, and even on the slopes of hills, and grows like any other cereal, without irrigation, or any other attention than is bestowed on them. This grain seems to possess more of the farinaceous element than the ordinary rice, and is much prized by the northern people, who refuse to taste the southern rice if they can procure the other, saying there is no strength or relish in the former. We have also delicious glutinous rice, which is greatly sought after, and is raised especially in the neighbourhood of hot springs. (2) Wheat and barley stand next, and are largely cultivated, and "bannocks" of barley meal and wheaten flour are as common in North China as in Scotland. (3) The third great food staple is millet, which is universal in North China. On good ground it attains an average height of twelve or thirteen feet, on poor soil about eight or nine. The leaves are long and graceful, much like the leaves of Indian corn, only narrower; they grow alternately on opposite sides of the stalk, one at each joint, the lower part of

the leaf forming a sheath around the stalk. When the stalks are full-grown the lower leaves are stripped off to let in more light and air about the roots, and are stored away for fodder. The ear or head is what botanists call a compound panicle, and forms the top of the stalk. It is at first a short roundish tuft, but as the axis or stem grows, the panicle gets longer and more bushy. A full well-grown head consists of fifty or sixty branches or peduncles arranged in whorls about an inch apart, each whorl having from three to five peduncles—the last whorl forming the top of the panicle. Each of these peduncles again branches, giving off about seven small peduncles, borne alternately on opposite sides of the larger peduncle. From these spring a few still smaller peduncles, also alternate and opposite, each of which is crowned with one, two, or three grains. The best heads contain as many as 3,000 seeds. The seeds are about the size of duck shot, and slightly oval. The system of flowering is the same as in wheat. As the grains swell they grow upward out of the husks till fully half the seed is exposed. The sowing takes place in April or early in May, and the grain is usually ripe by the beginning of September. While requiring good soil for its full development, it will grow on almost any land.*

There are three sorts of *kao-liang*, the red, white, and brown, or light yellow, as the Chinese say. Of the red there are two sorts, one with seeds and husks, both red, and one with red seeds and black husks. There are also two varieties of white, one having both seeds and husks white, the other having white seeds and black husks. The white sort is used exclusively for human food, and when cleaned and boiled looks very much like pearl barley. But this *kao-liang* not only affords food for man and beast, but it is useful in a great variety of ways. The strong stems make excellent lathing for partitions, walls, and roofing for houses; also the tall strong stems are used for pallisades around their dwellings; the inferior sort for fuel; while the light spongy pith of the stalks makes admirable tinder and match lights.

The (4) fourth is paincum, of which we have three chief varieties, (1) spiked paincum. Though the *kao-liang* is the most conspicuous of the northern cereals, spiked paincum, with its long, drooping, catkin-like heads, is undoubtedly the most graceful. It is sown loosely in drills eighteen inches or two feet apart. Usually

* See *North China Herald*, from which I take this description.

each seed produces only one stalk, though some give off one or two suckers from the root. On good land the stalks, when full grown, are at least four feet high. On rich land the average length of the ear or spike is from ten inches to a foot; on poor soil, from seven to eight inches. The seeds are pale yellow, and are very small. This is the most productive grain in the world. On an ear eleven inches long, the writer in the *North China Herald*, from which we are quoting, says:—"We have reckoned 11,300 grains, and the best ears are said to contain 20,000 seeds each." This entirely harmonises with calculations I myself have made in former years. The spike is made up of about 113 short branches or peduncles arranged in whorls, three or four in each whorl, along the axis or stem. The peduncles become gradually shorter towards the top, and thus form the spike. The straw is thick and succulent, like rice straw, and, cut into chaff, makes an excellent fodder for horses.

Panicled millet differs greatly in appearance from spiked millet while growing, though the seeds are nearly indistinguishable, being only a little larger and yellower. An ordinary-sized panicle contains about 1,160 seeds, and as each root produces on an average six such panicles, it follows that one seed yields on an average 6,960 grains. There are two kinds of panicle millet; one is called *shu-tz* and the other *mei-tsz*, but they are so much alike in every respect as to be indistinguishable by the uninitiated. The *mei-tsz* is not glutinous, and yields excellent flour for making cakes and buns. The *shu-tsz*, which when cleaned is called *huang-mi*, or yellow rice, is starchy, and makes a palatable and nutritious porridge.

(5) Indian corn and buckwheat are also extensively cultivated in the northern provinces.

(6) We have also an immense variety of beans, pease, and pulse, large and small, yellow, black, green, and variegated, the yellow being chiefly used for producing oil and bean cake, which is exported to Foo-Kien as manure for the sugar cane—the black being used chiefly as food for mules and horses—and the small green variety for food, and especially in the preparation of vermicelli.

(7) Sugar cane is cultivated in many parts of China.

(8) Tobacco is grown largely all over the west and north—a recent importation from Japan through the Dutch.

(9) Opium, alas! is now extensively produced in all directions in west and north.

(10) Of vegetables there is no end. And it may be interesting to notice that we have now at the ports not only the native edibles, such as sweet potatoes, Irish potatoes, ground nuts, turnips, etc., etc., but also all our best European and American vegetables, beginning with the early cabbage and pease in spring, and ending with the Cauliflower, Brussels sprout, and Brocoli in winter.

(11) *Fruits.*—So also with fruits, we have native cherries, apricots, peaches, nectarines, plums, apples, grapes, pears, persimmons, dates, pomegranates, arbutus, etc., in endless variety; but we have also introduced the strawberry, raspberry, and cultivated brambles, which are simply delicious.

(12) *Salt.*—The distribution of salt in China is very marked. In Shan-si, Shen-si, and the north-west generally, we have salt lakes of greater or lesser extent which provide the natives with an unlimited supply. In Sz-Chwen we have wells sunk after the Artesian manner, many over 1,000 feet deep, which yield salt brine in large quantities. Near these are pretroleum springs which rise to the surface. The gas is lighted, the brine passed over the flame, and the salt thus procured. Still farther from the sea than either of these provinces, viz., in Yunnan, we have a like remarkable provision—not natural tanks as in Sz-Chwen, but clay, &c., wonderfully impregnated with brine in many hill-sides, into which tunnels are driven and the indispensable condiment obtained.

(13) Of *Spices* we have all varieties.

(14) In regard to *Tea*, I would only say this, that, like some other products of China, the virtue is found to lie not altogether in the plant, but in the soil and environments, so that Chinese tea is never likely to be superseded, but will always form the "body" of our beverage. This is especially the case with the far-famed Puerh tea of Yunnan, which is exported to all parts of China, made up in small cakes, seven of which usually form a package, and which are wrapped in palm leaves, making a parcel of about 4 lbs. This tea is said to afford seven infusions without being reduced in strength and flavour!

Textile Fabrics.

(1) *Silk.*—China is the home of silk. Their first Empress, B.C. 2600 (semi-historical), is represented as teaching her maidens how to cultivate the mulberry tree, rear the silkworm, unreel the cocoon, and spin the thread. And in the tribute of Yu, B.C. 2200

—one of the most interesting and authentic of the heirlooms of antiquity—we have several kinds of silk mentioned as the tribute from different districts, *e.g.*, wild silk, "deep azure silk," "fine floss silk," "purple silken fabrics," silken fabrics, and so on. Very generally produced in those days, it has continued to be a speciality in China during its lengthened history, and at present its distribution is something remarkable. I cannot recollect of any district in China which I have visited, north, south, east, or west, where I have not met silk culture in some form or other. It was one of the great articles of merchandise in ancient times. I have no doubt the silk of which Solomon spoke, B.C. 1000, came from China; so also the gorgeous silk robes in which the ancient Persian monarchs adorned themselves, as well as the silks of which we hear among the Greeks and Romans. Indeed, it is expressly affirmed in the account of the Greek voyage made by order of Alexander the Great between the Indus and Euphrates, and in reference to the trade in India, "that the silk came from countries further east." During the Roman empire an embassy visited China in A.D. 166, and took back silks from Cochin China. Another embassy sailed up the Yang-tse Kiang to Nanking by order of the Emperor Justinian. Later on two Nestorian missionaries brought silkworm's eggs preserved in canes. This was the beginning of silk culture in Greece, whence it spread to Italy, France, and even to the West of Ireland.

(2) *Hemp.*—As with silk so also at the very commencement of their history we find the Chinese with a knowledge of Hemp, and acquainted with the art of weaving it; and in our time we find a great many varieties of this important plant—(1) the common Hemp, *cannabis sativa*, L.; (2) the *Abutilon avicennae*—both used for making ropes; (3) the *corchorus capsularis*, L., resembling the Jute plant of India, and which grows like little fir trees; (4) the *Boehmeria nivea*, Hooker, or stingless nettle, from the inner bark of which the Chinese grass cloth is made, and which is found extensively in South and Central China; (5) the *Pueraria Thunbergiana*, from which a coarser grass cloth is prepared.*

(3) *Cotton.*—This plant is a comparatively recent introduction into China, but is now most extensively grown. There are two chief varieties, one white and the other yellow, from which the famous Nanking cloth is made. The staple of both is short but

* On these and kindred topics, see Bretschneider's works.

firm: the cloth is strong and durable, far surpassing our manufactured fabrics. There is a third variety, very strong, used for money bags and sacks.

(4) *Paper* is manufactured from a great variety of sources:—(1) the bark of the bamboo; (2) the inner rind of the mulberry tree; (3) wheat straw; (4) the bark of the plant *Wiks-troemia*, from which a strong paper, useful for packing, is prepared in large sheets; also (5) from two species of the *Edgeworthia.*

Oil-Producing Plants, &c.

In addition to Pulse, of which we have already spoken, we have (1) the seeds of the *Perilla ocimoides*, L., *a Labiate;* (2) Sesamum; (3) Tung yew, or Tea Nut oil—a most important article of commerce; (4) certain cruciferous plants, the seeds of which belong to the genera *Brassica* and *Raphanus*, one especially, with yellow fragrant flowers, which grows extensively in Kiang-soo, Che-Kiang, and elsewhere; and others of a similar character, and which grow in Sz-Chwen, Hunan Hupeh, and Yunnan, from the seeds of which much oil is compressed; (5) Rape.

Wax.—The white insect Wax is another important product of China, and is coming fast into general notice. It is produced by a small insect, the *Coccus-pela*, which lives on the leaves of a species of ash, viz., the *Fraxinus Chinensis*, which is found extensively in Central and Western China.

The Tallow tree is another curious production of China, and of great value.

Dyes.

First of all, in extent and importance, stands Indigo, which is procured from several different plants (1) a leguminous shrub, viz.:—the *Indigofera tinctoria*, L., (2) *Indigo anil*, L., a larger plant of the same character, (3) *Polygonum tinctorium*, an acanthaceous which grows in North China and Manchuria, (4) the *Isatis Indigotica*, a cruciferous plant, (5) a plant which some suppose to be identical with the *Strobilanthes fluccidifolius*, which in Assam produces the celebrated blue called Room. Second, the green vegetable dye, which created such a sensation about thirty years ago. It is procured from the bark of a Rhamus which grows plentifully in the provinces of Che-Kiang, Sz-Chwen, and mountains near Peking. Third, Madder. Fourth, Safflower, besides others of less importance.

Lacquer.—This famous varnish is procured from several species of the Sumac *Rhus* or *vernix vernicia*, and the *augia sinensis*, and is found in many parts of China. The best kinds cannot be surpassed, and is also one of the most ancient products of China.

The Geology of China.

On this time will only permit a few words. There will therefore be nothing for the specialists, and I will confine myself to the economic aspect. All geologists who have traversed China have remarked the great simplicity of structure which prevails throughout its whole extent. Underneath all we have, of course, the metamorphic rocks, gneiss, granite, and primitive schists. Above these are limestone—in many places tremendously developed. Pumpelly makes a calculation which gives 11,600 feet. On this, as a floor, lie the coal formations, and above them sandstone, clays, etc., etc. The granite in many parts of the country rivals our finest Aberdeen granite; and in every quarter we find limestone converted into marble, giving us thus beautiful ornamental stone of all colours and varieties, and in all degrees of fineness.

But the great feature is the coal formation and deposits of iron.

Baron von Richtofen, who had been engaged in the survey of the Western States of America, when he heard of the coal-fields of China, came over with the view of placing his great scientific skill at the disposal of the Chinese Government. His services were declined. He made several journeys on his own account, and ultimately was requested by the Shanghai Chamber of Commerce to investigate the mineral resources of the country. Preliminary reports have already appeared, and his great work is partly published. He found not only the statements already published regarding the mineral wealth of China true, but made great additions to our knowledge. In the province of Hunan he discovered a magnificent coal-field of no less than 21,000 square miles in extent. Of this he says:—"The inclined position of the strata makes mining tolerably easy. The situation is no less advantageous. Many mines are worked close to the river side and at little distances from it; there is thus direct water communication with Hankow. The coal in this district is all anthracite. I think it will compare favourably with the best kinds of anthracite known."

In his last journey he found another coal-field near Juchow, about 23 miles broad, having seams ranging in thickness from 6 to 8 feet. Not far from the city of Honan-foo he came on a third field of considerable extent, with seams varying from 6 to 18 feet. At Tai-Hang-Shan he estimated the quantity of coal produced, even by their rude methods, at between 200,000 and 300,000 tons annually. He then entered Shan-si, and confesses himself perfectly amazed at the extent and quality of the coal-fields of that province. He says that, as far as he knows, they are not equalled in the whole world. He speaks of the remarkable simplicity of structure, and calculates their area at somewhat about 30,000 square miles. The coal formation in this province is about 500 feet in thickness, and many of the coal beds 30 feet thick. He also remarks that carboniferous strata lie far above the level of the plain, so that railways or tramways could be carried right into the seams in the mountains and loaded on the spot. He admits the disadvantage of being so far from the sea or water communication, but asserts that the superiority of the Shan-si coal over the coal near Peking will more than counterbalance the extra expense of carriage. The disturbed state of China at that time put an end to his investigations; and we are thus left without any account from actual observation of the coal-fields in Western and Southern China. In lieu of this we have the next best authority, viz., Mr. Pumpelly, who took the trouble to employ Chinese scholars to investigate native books in reference to minerals. Fortunately these are numerous and accurate, every department and district—*i.e.*, "foo" and "hien"—having its own gazetteer. By the help of his Chinese secretary he examined over one thousand volumes. Taking the information contained in them in connection with observations of European travellers, he made a hypothetical map of China proper, showing the position and extent of the various formations. The correctness of this map has been verified in several instances, and may be taken, at all events, as a good approximation of the geological structure of the country; and what a stirring tale it tells! The disclosures are perfectly astounding. He shows that under every one of the eighteen provinces—each of which, be it remembered, is about as large as Great Britain—there are large deposits of coal.

In some provinces coal underlies the whole country, coal of all descriptions—bituminous, anthracite, cannel, and lignite—much of it equal to the best found in any part of the world, as has

been verified by scientific men in Europe and America. To bring out the extent of the coal-fields, as clearly as possible, I shall make a tabulated comparison between them and those of Europe.

In the official catalogue of the Great Exhibition (vol. I., p. 181), Professor Ansted gives the undernoted as the coal area of the following countries :—

British Islands, ...	12,000 square miles.
France, ...	2,000 "
Belgium, ...	520 "
Spain, ...	4,000 "
Prussia, ...	1,200 "
Bohemia, ...	1,000 "
	20,720 "

Place this side by side with what we know of China :—

Province of Hunan, ...	21,000 square miles.
" Shan-si, ...	30,000 "
" Chih-li, Shan-tung, and Southern Manchuria,	84,000 "
" Sz-Chwen, say	70,000 "
" Shen-si, ...	25,000 "
" Kan-suh, ...	20,000 "
" Honan, ...	10,000 "
" Kwei-Chow, ...	14'000 "
" Kwang-si, ...	13,000 "
" Kwang-tung, ...	23,000 "
" Hupeh, ...	5,000 "
" Fuh-kien, ...	25,000 "
" Che-Kiang, ...	6,000 "
" Kiang-si, ...	35,000 "
" Ngan-Whiu, ...	4,000 "
" Kiang-su, ...	4,000 "
" Yunnan, ...	20,000 "
	409,000 "

Here we have, in Hunan, a coal-field larger than the aggregate of all the coal-fields of the greatest coal-producing countries in Europe; in Shan-si, another coal field one and a-half times larger than that aggregate; while in the other parts of North China, we have coal-fields seven times greater than all the coal districts in Great Britain, and so with the other provinces. Or, looking at it in another light, we have 409,000, or nearly half a million,

of square miles of coal in China. This is sufficiently startling; but there is another fact connected with this matter, which adds tremendously to the importance of these figures. Side by side with all the coal-fields explored are iron-ores and iron-stone of all descriptions; and, most remarkable of all, the commonest in North China is the black oxide of iron—true magnetic iron-ore. So extensively does this prevail, that the natives use only this variety in the preparation of their iron utensils, and pass by fields of other iron-ore and iron-stone which would be perfect fortunes to manufacturers in our own country. The writer speaks of what he has seen; for he has picked this iron-ore out of the ground, found it to contain from 60 to 80 and 85 per cent. of pure iron, and, placing it among needles, found it a magnet of the most powerful description.

The other minerals, such as gold, silver, copper, lead, tin, and quicksilver, are upon an equally magnificent scale. Not a province which does not contain less or more of each, while in some they exist in great profusion, so that I am within the mark when I say that, excepting the stupendous mineral wealth of the Western States of America, there is no equal to them in the world. Nor is this all; in addition, we have precious stones, as jade, amethyst, topaz, beryl, lapis-lazuli, sapphires, garnets, pearls, emeralds, rubies, diamonds, turquoise; also we have clays of all descriptions; marbles of all degrees of quality and shades of colour; salt wells and salt in different provinces; petroleum springs in Sz-chwen and Shan-si, producing apparently inexhaustible supplies; lime, sulphur, alum, borax, and in fact everything needful in the arts and manufactures, as well as countless quantities of nitre, soda, potash, magnesia, and all the ingredients necessary for artificial manures, in most provinces, often in great profusion. The island of Formosa is said to be one storehouse of sulphur.

TRADE ROUTES.

As regards the south-west of China, there can be little doubt that the most advantageous in every way is that advocated by Baber, Colquhoun, and others, viz., through the Shan country, and emerging at Maulmein. At the same time I do not despair of the other route, *via* Bahmo to Ta-li-foo, and the Yang-tse Kiang. Certainly it is the most direct route, would save great mileage, time, and sea insurance, connect with our system of Indian railways, and, by touching the Yang-tse Kiang and tapping the exceptionally fine province Sz-Chwen, would soon create a trade for itself; and so it is

quite possible the exigencies of commerce and the enterprise of our engineers may yet overcome the several alpine ranges, of which so much has been made. One thing is clear, the telegraph wires will soon cross the country in that direction.

But, after all, the most practicable route for heavy traffic is one of which little has been said, but which is sure to be adopted sooner or later, namely, *via* Honan, Shen-si, Kan-su, and Central Asia. Nature may almost be said to have anticipated this road, and made provision for it. To use the words of Baron von Richtofen, "if an engineer were to construct an imaginary cut through a high mountain range for laying a convenient railroad track, he could scarcely solve his task more perfectly than nature has done in this gigantic cut, thousands of feet deep, one hundred li ($33\frac{1}{3}$ miles) in length, which crosses all the parallel ranges comprising the Foo-nieu-Shan hills. The grade is so gentle and the width of the passage so favourable that a railway could be laid down without the slightest difficulty."* And what renders this striking passage between Southern China and the North-west of Asia more important is (1) that it is the only possible one, owing to tremendous mountain ranges; (2) that it is the entrance to a populous country, kindly people, and fertile plains; and (3) the remarkable circumstance that it traverses the great coal-fields of Shen-si and Kan-su, and, in fact, has coal all along its line as far as Ili, as many as thirty degrees of longitude. As Richtofen says, "there is scarcely one instance on record where so many favourable and essential conditions co-operate to concentrate all future intercourse on so long a line upon one single and definite channel."† This road bifurcates at the oasis of Hanoi—of which so much has been spoken, the southern route leading from Hanoi to Yarkand, Kashgar, Khoten, and Persia—and is the route which has been used by caravans long anterior to the Christian era. The other takes a north-westerly direction to Bar-Kul, Kuldja, and thence to Russian territory. On the principle of circular sailing this route would be by far the shortest. The great difficulty is Russia, but surely this cannot prevail for ever.

The People.

Origin.—Though somewhat outside my subject, yet a few words on the Chinese people appear indispensable to this paper. Recent

* Letter on Honan and Shansi, p. 4. † Letter on Chih-li, etc., p. 38.

discoveries in philology, certain striking coincidences in their knowledge of astronomy—*e.g.*, names of planets, designations of several of the months, and character of their cycles—resemblances in their semi-legendary history, correspondences in their manners and customs—all show that the ancestors of the Chinese dwelt in the Upper Euphrates Valley, with the ancestors of the Accads, the early Babylonians, and the progenitors of the Egyptians. And, I may add, similarity in their religious systems, wonderful analogies in their methods and formulæ of divination, agreement in the divisions of their year, the periods assigned to rain-fall, heat, cold, &c., &c., prove that intercommunication existed from their earliest historic period—after they had established themselves in China—viz., from B.C. 2200 down to the Christian era, or rather to comparatively recent times: for there has hardly been an epoch when travellers did not go and come between China and the West by land or sea, or made the round trip, like the Buddha Priest who (A.D. 399-415) went through Central Asia and India, and returned by Ceylon, the Straits of Singapore, Java, and thence to Shantung.

Race.—The conclusion from this is that they are Hamites, and have the same blood in them as those vigorous races who formed the commanding, distinguished, and enterprising empires of early times—viz., the Early Assyrians, Egyptians, Phœnicians, and Hittites. Observe, it was Canaan who was cursed, not Ham; and doubtless the curse took effect only upon Canaan himself and the children he begot after, not before, the affliction. And in this way the peculiarities of the Negro race may be accounted for. The Chinese have passed through many revolutions, but they are the same people, with the same government and traditions, and are thus the most venerable nation on earth.

Population.—According to the Chinese official returns of the Board of Revenue, quoted by our late Ambassador, Sir Thomas Wade, the population in 1881 was 285,000,000, and may now be reckoned at 300,000,000, or about 200 to the square mile; not a high figure, for the population of England and Wales is 414. The population of the provinces vary from 600 in a square mile in Kiang-soo, 500 in Chih-li and Shan-tung, to 47 in Yunnan.

THE BEARING OF ALL THIS ON THE FUTURE.

But it is time now to consider the bearing of all this not only upon the future of that Empire but on that of other countries. I will,

however, leave a great deal for your own reflection. A few words must suffice. Here then we have a country possessing a magnificent area, a wonderfully varied soil, rich commercial staples, unsurpassed water communication, great fields of coal and iron ore under every province—some of them most extensive—not a few extremely accessible, and the whole combined forming a development equalled only by the Western States of America: a country possessing every chemical in large quantities needful for manufactures or for the artificial enriching of land, and every substance required either for human comfort or luxury, or necessary for the extension of man's dominion over nature; a people who have led the way in the East for 4,000 years, and given their civilisation and their literature to all the surrounding nations; a people as fresh and vigorous as ever, and apparently entering on a grander career than they have yet passed through; a people among whom education and intelligence are wonderfully diffused; a people of high intellectual development, minds trained by discipline, hands skilled to work, a doggedness which is proverbial—capable of overcoming every obstacle, and a will resolute to put everything in motion for their own ends; a nation of extraordinary vitality, whose existence for so many milleniums proves that they have a capacity for organisation and government of no ordinary kind; a people whose institutions have been of a higher description than those of any other nation and better worked—one of which, viz., their competitive examinations, forms a ladder reaching down to the humblest classes, and by means of which the brightest and ablest men in that vast population have been selected to fill positions of responsibility and rule, from the ordinary county magistrate up to the highest position in the State; a provident people, not like the Hindoos, burning what would constitute their best manure, but carefully preserving everything, solid and liquid alike, capable of returning to the soil that which has been extracted from it—proving the accuracy of their observation, when, without science, they have found that all sorts of things, and even hair, parings of nails, the sweepings of their barbers' shops are all profitable for agriculture; their farmers alive to everything which will conduce to the outcome of their fields, and who, as soon as they discover the advantages of the selection of seeds, artificial manure, and the new machines now invented, will infallibly adopt them and ultimately double or treble the produce of their country. Their business men, keen, far-seeing, and possessing a perfect

passion for commerce. An enterprising people. This has been their characteristic in all ages. Long before the Christian era their keels ploughed the Eastern seas; and there is evidence that somewhere in the Indian Ocean, or it may be the Persian Gulf, their junks met the ships of the early Phœnicians and exchanged the merchandise of the East with the West They are so still. And the safety, economy, and regularity and speed of our steamers have given a tremendous impetus to this feature of character among them. They are swarming out in all directions, not only to well-known places in the Malay Archipelago, but to the remote islands of the Southern and Eastern seas. They will assuredly occupy New Guinea; and I have just heard that the pioneers of this great ant hive have snugly located themselves on the coast of Africa.

And what will be the result of this? First, they will introduce a measure of civilisation; but more important still, they will bring these islands and countries under cultivation, and so make them sources of food supplies—first for China and then for other nations. And, seeing we are told that a definite piece of ground which would support only two men if sown with wheat would sustain fifty if planted with bananas—what may we not expect as the result of their labours in these rich, fat, luxuriant peninsulas and islands hitherto so unprofitable—only masses of jungle? A people which delights in elegance, not content with the mere necessaries of life, but always aiming at greater wealth and higher position; and, as they gain it, gratifying their tastes in the improvement of their houses, the adornment of their dwellings, the beautifying of their gardens, and especially the enriching their dress. And one of the most interesting sights in China is a group of Chinese exquisites in a tea garden on one of their artificial lakes during a summer afternoon, where the arrangement of their apparel and assortment of colours, from their spotless satin embroidered shoes up to their tiny collar, is matched only by the rich and gorgeous dress of their ladies, and surpassed by nothing but a butterfly. A wealthy people! And this is an important aspect. They have been gathering the gold and silver and copper, &c., from their streams and mines during all periods of their history; and there never have been—as repeatedly in Europe, Asia Minor, and India—invading powers which have overrun their empire and robbed them of their treasures. The Mongols once conquered it, and the Manchus hold it at present, but it is the case of the conquered conquering the conquerors. These warriors located

themselves in their capital, and assimilated themselves to their institutions and civilisation. Thus the accumulation of precious metals for 4,000 years still remains in the country; also the wealth amassed by commerce with outside nations, and the tribute of their dependencies—all are in China still. And those who have resided among them know that this wealth is not possessed by a class, but is very widely distributed among the people in all parts of the land—buried at present, for the most part, owing to the unsettled state of the country, and the instability of the Government and consequent rapacity of the officials, but still there, ready to be expended whenever the people feel secure in the enjoyment of it.

There is, therefore, no country in the world where there is such a prospect for commerce; for it is not the extent of territory, as in our young colonies, but the wealth, tastes, and number of the population that commercial men have to look to. And just in proportion as the Government gathers strength and the people confidence will our trade change and enlarge; and I anticipate that the turn which has already taken place will go at a greatly accelerated rate, and we will find the Chinese not contenting themselves with our piece goods, woollens, etc., etc., but manufactured articles of economy, beauty, taste, and luxury—machinery of every description, and fabrics of all kinds, and articles of use and elegance in iron, steel, silver, and gold. And how many wheels will the new and emancipated commerce of 300,000,000 set agoing? Great as it is at present, it will be absolutely nothing to our future trade if we are only true to ourselves.

A wise, cautious, but a people decidedly advancing; for, observe, one of the characteristics of the Chinese is this, they will take advantage of everything which will conduce to their interest. And this is true of all classes—agriculturalists, manufacturers, merchants, literary men, and rulers alike. They are tentative and careful, and take their time, but once convince them of the utility of anything, and it is as sure to be adopted as the sun is to rise. They have proved it already on a small scale in all departments. They have adopted, in a measure, our arms, steamers, lighthouses, dredging machines, printing presses, telegraphs, mining machinery, international law, science, and are beginning to receive our religion. This feature of their character is the most significant of all, and can be unhesitatingly relied upon.

It has been said their civilisation was non-progressive. It would be better described as limited. Six or eight times in their history, especially during the Chow, Han, Tang, Soong, Ming dynasties, and during the present dynasty, they reached a certain height of civilisation, but have as often fallen back, risen again and fallen back again, all, I believe, for the want of that strength, hallowed enthusiasm, and elevating principles which Christianity alone can supply. But they are human; and to be human is to be progressive; and so we find leading men in all classes, and especially men in high and responsible positions among them, open to every suggestion, weighing every plan, and adopting every means which commends itself to their judgment.

This feature is the hope of us all. When they saw the absurdity of their self-conceit and exclusiveness, they had the good sense to throw their pride to the winds, and to open their minds to suggestions from every quarter, to strengthen their Government and their position among the nations by sending ambassadors to the courts of Europe and America, reorganising, drilling, and equipping their army with the most formidable weapons, creating a new navy of the most powerful iron-clads, spreading a network of telegraphs over the empire, opening their mines and preparing themselves in every way to meet the exigencies of the age. And the younger men among them are now all eyes and ears, straining every means to master Western science, and ambitious to qualify themselves to sustain the responsibility of their nation, and the grand tradition of their country when their turn comes.

The Marquis Tseng said the other day at Folkestone—"It is affirmed that the Chinese wish to avoid intercourse with foreigners. That is not true. We do not fear contact with foreign nations. Nay we court it; for we know the advantage of that." This statement is true, as I can testify from much personal knowledge. "They know the advantage thereof," not commercial advantages merely, nor even intellectual advantages, but the advantage of being permitted to rely on Britain, or rather on generous-hearted, high-souled British gentlemen, for guidance and help in their hour of need, and amid difficulties consequent on a new departure. Let me commend China to your sympathy. What we give to her in the matter of patience, consideration, and fair play, she will repay to us one hundred-fold.

XV.—*On the recent progress of Chemistry at Home and Abroad: A plea for the Teaching of Higher Chemistry in this Country.* By J. J. Dobbie, M.A., D.Sc., Assistant to the Professor of Chemistry, University of Glasgow.

[Read before the Society, 6th February, 1884.]

"Mr. Millbank liked nothing so much as an invention, unless it were an experiment."—*Coningsby.*

CONTENTS OF PAPER.

Progress of Chemistry in England in recent years—Some causes and results of progress considered—Progress in England compared with progress abroad, especially in Germany—The statistics employed, based chiefly upon the literature of Chemistry—England is behind in Organic Chemistry, and in those branches of the science which involve a knowledge of cognate subjects—As regards manufactures, England holds her own in those which involve only a knowledge of principles which have been long known, but is behind in those which involve a knowledge of recently discovered principles—Value of German research estimated, (1) even when not original in the strict sense of the term, it aids the progress of the science by accumulating facts upon which subsequent generalisations are based; (2) It supplies the country with a large body of highly-skilled chemists to whom the rapid development of chemical industries in Germany is mainly to be attributed—The causes of the backward condition of Organic Chemistry, and of special branches of the science in this country considered; they are (1) the want of properly organised "Schools" of Chemistry such as exist in every German university; (2) failure of many of our manufacturers to recognise the advantages of a liberal chemical education over a narrow technical education—This arises out of a misapprehension as to the causes of the progress of Chemistry in Germany, which has been due, not to technical schools, but to the universities, from which nearly all the great discoveries of recent years have proceeded — The great need of Chemistry in this country is the establishment of schools, inside or outside of the universities, which shall provide teaching in every department of Chemistry, adequate laboratory accommodation for the prosecution of research, and a general education equally liberal with that which the German chemist receives.

In the following paper my object is not to give an account of the progress of chemistry in recent years, but to draw attention to certain facts, chiefly connected with the literature of the science, from which the rate of progress in different countries may be inferred and compared. I shall not attempt to describe the discoveries by which the science has been enriched, but shall endeavour to draw, from the number and distribution of those discoveries, important lessons as to the condition of chemical teaching in this country.

Without looking at all narrowly into the facts, it must be apparent to everyone that within recent years the study of chemistry has been receiving an ever-increasing amount of attention. Nor is the cause of this far to seek. Not many years ago the word "chemist" was almost synonymous in popular language with "druggist," and the word "chemicals" with "drugs." But the recent application of chemical science to nearly every branch of manufactures has gradually tended to correct the popular misconception. Chemistry, people begin to see, has to do with all kinds of manufactures—with the production of steel as well as with the preparation of citrate of iron, with the production of yarns as well as with the preparation of aniline dyes. It seems not unlikely that, in time, the name chemist may pass away altogether from the druggist, and the original popular use of the term be entirely lost.

The increased attention bestowed upon chemistry in this country has been due to causes totally different from those which have given so powerful an impulse to the study of biology. The awakened interest in chemistry has been of a purely practical kind. It has been due to the ever-deepening conviction that a study of the principles and methods of this science is capable not only of stimulating existing industries but of opening up entirely new fields for the display of the practical skill and energy of our people. It has needed no popular literature to commend it; it has required no popular teacher to expound it. By the want of a popular school the science has no doubt suffered. Attention has been too constantly devoted to its immediate practical aspects, and its teachers have sometimes been deficient in that breadth of view and sympathy with other departments of knowledge without which no science can attain its full development. But, on the other hand, it has perhaps been saved by this very want from the baneful influence of too hasty and presumptuous generalisation.

While chemistry has little or no popular literature, in technical literature it is perhaps more prolific than any other science. Not including distinct volumes, three thousand (or eight for every day of the year) is certainly a very low estimate of the number of papers and memoirs on chemical subjects published throughout the world in the year 1882, and professing, for the most part, to contain the results of experimental work. To glance through such a mass of writing would for a single individual be a task, to examine it an impossibility. But, without attempting this, I

believe we can arrive at important conclusions by attacking these papers—after the fashion set by Lord Macaulay of treating otherwise unmanageable literature—from the statistical side, the only side, indeed, from which they are assailable.

It would not be safe, perhaps, to consider mere increase in the bulk of chemical literature as an exact measure of the progress of chemistry; but, on the other hand, there can hardly fail to be some relation between the amount of work done and the amount of literature produced in any given department of science. It is upon this assumed relationship that the following paper is based.

It is not possible to make an exhaustive list of the papers on chemical subjects published in this country in the course even of a single year. Many contributions of value are buried in the journals of local societies or in those of special industries, where it becomes impossible to trace them. But nearly all results of value and of scientific as opposed to technical interest ultimately find their way into the *Journal of the Chemical Society*, the *Philosophical Magazine*, or the *Transactions and Proceedings of the Royal Society*. Although the *Chemical News* sometimes contains papers of great value, it is not made up for the most part of original matter. The journals of the Pharmaceutical Society, of the Society of Chemical Industry, of the Mineralogical Society, and the *Analyst*, each devoted to a special department of the science, complete the list of our periodical publications in chemistry.

Turning first to the *Journal of the Chemical Society*, it will be seen that there has been a gradual increase in the number of papers contributed to this Society since 1870. In 1869-70, 35 papers, of of which 13 were upon subjects connected with organic chemistry, were read before the Society; and in 1879-80, 75 papers, of which 28 were upon organic subjects.

TABLE I.

Table showing Number of Papers published in the *Journal of the Chemical Society*, 1870-1881.

.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1789.	1880.	1881.
Total, ...	39	28	32	46	49	49	56	59	61	84	75	75
Organic, ...	14	14	18	14	30	22	26	24	25	34	13	30

The accompanying Table gives the number of papers published in the Journal from 1870 to 1881. For reasons to be explained hereafter, the number of papers on organic chemistry, as well as the total number of papers for each year, is given. But it must be remembered that a strict classification is impossible, and papers which I have classed as organic would possibly by others be placed under a different heading. The Table shows that the number of papers published by the Chemical Society has more than doubled within the period examined—the increase being a steady one—while the proportion of papers on organic subjects to other papers has remained almost unchanged.

During the same period, however, the number of chemical papers contributed to the *Philosophical Magazine* and to the Royal Society has not increased.

If we turn from the literature of the subject, still more striking evidence of the progress of chemistry in this country will be found in other directions.

Within the last ten years nearly all our great Universities and Colleges have revised their courses of study, and given increased prominence to science, and especially to the science of chemistry. Old degrees have been widened in their scope, and new degrees have been created. Cambridge and Oxford have not been able to resist the spirit of the age, and now offer their highest honours and rewards to the student of science as well as to the student of classics. Within the last ten years nearly all the great towns of England have, by the public spirit of their citizens, or by the munificence of private patrons, been provided with the means of higher education than the public schools afforded. Since 1870 no fewer than ten Colleges have been founded throughout the country, in all of which the teaching of chemistry occupies a prominent place.

The work done by the Science and Art Department in promoting the teaching of science in our schools has also greatly extended. In 1871 the number of passes in the different stages and departments of chemistry was as follows:—In organic chemistry, 1st class, 11; 2nd class, 61. In inorganic chemistry, 1st class, 373; 2nd class, 1,340. In the advanced stage in organic chemistry, 1st class, 7; 2nd class, 11. In inorganic chemistry, 1st class, 72; 2nd class, 282. In 1879 the numbers had increased in the elementary stage in organic chemistry to 118 in the 1st class and to 63 in the 2nd class; in inorganic

chemistry to 1,084 in the 1st class and 1,602 in the 2nd class; and in the advanced stage in organic chemistry to 16 in the 1st class and 25 in the 2nd class; and in inorganic chemistry to 258 in the 1st class and 466 in the 2nd class.

Within the last two or three years the City and Guilds of London Institute has begun with great success to do for the various branches of applied chemistry what the Science and Art Department aims at accomplishing in pure chemistry.

Hardly less remarkable than the increase in the number of colleges has been the recent growth of new societies connected with chemical science. The Institute of Chemistry, which aims at ascertaining and certifying the qualifications of professional chemists; the Society of Chemical Industry, which has for its object to unite, for purposes of discussion and for the better diffusion of technical knowledge, the industrial chemists of the country; the Mineralogical Society, and the Society of Public Analysts have all arisen within the period under review.

Legislation also has exercised a most important influence upon the progress of the science.

A narrative of what crime has done for chemistry would form an interesting chapter of scientific history. We owe much of our knowledge of mineral poisons to the necessity, created by the subtle ingenuity of criminals, of accurately studying the properties and reactions of these substances. The frequent trials under the Adulteration of Foods Act are rapidly promoting the accurate study of the composition of food stuffs and other articles of consumption which are liable to adulteration.

The Pharmacy Act, the educational provisions of which were first made compulsory in 1868, has effected a revolution in the training of our pharmaceutical chemists, and we may hope soon to possess in this country a body of pharmacists rivalling in celebrity those great corporations of France and Germany, which have furnished so many names to the roll of illustrious chemists.

The Alkali Acts, the Rivers Pollution Act, and other legislative measures have conferred as great a benefit in many instances upon the industries which they immediately affected as upon the community in whose interests they were originally passed. If anyone doubts the influence of such measures, let him turn to Lomas' "Manual of the Alkali Trade," to the Blue Book containing the Report by Dr. Ballard of the Islington Board, or to the history of the development of any of our great chemical industries,

and he will see how intimate is the connection between improvement and the compulsory disposal of waste products otherwise than by passing them into rivers or the air. Many special instances might be given. I shall content myself with one taken from a foreign source, but not on that account the less instructive. "The attention of the French Government having been called to the pollution of the rivers which receive the washing liquors of the garancine manufacturers in the neighbourhood of Avignon, they were called upon to devise some method of abating the nuisance. M. Pernod, one of the largest manufacturers of garancine and 'fleurs de garance' in the department of Vaucluse, gave to the subject his attention, and contrived a process by which he not only removed nearly the whole of the organic matter in suspension, and neutralised the acid, but even effected a saving, for he discovered that the spent liquor of garancin contains a large quantity of oxalic acid."*

Last of all, I may mention amongst legislative influences the appointment of the Technical and other Royal and Parliamentary Commissions, and the establishment of the Research Fund, administered by the Royal Society.

Whether, then, we look to the literature of the subject, to the improvement and extension of the various agencies whereby chemistry is taught, to the increased number of societies, to the awakened interest of Parliament as shown in the appointment of recent Royal Commissions, it must be admitted that the history of chemistry in this country during recent years has been a history of continuous progress.

But, if we look abroad, we shall see that, while we have undoubtedly been advancing, other countries have been advancing with still more rapid strides. To be convinced of this we have only to compare the amount of original scientific work done in this country with that done abroad—especially in Germany and France. The abstracts published in the *Journal of the Chemical Society* afford a ready means of making the comparison; but for the two years to which I wish more particularly to call attention I have made an entirely independent examination of the literature.

From an examination of the accompanying Table (No. II.) it will be seen that, while the number of papers published in England which were deemed worthy of being abstracted was only 115 in

* Crace Calvert, "Dyeing and Calico-Printing," pp. 85-86.

TABLE II.

Table showing Number of Abstracts of Chemical Papers published in the *Journal of the Chemical Society* in the two years 1872-1882. Classified according to Subject and Nationality of Author.

	Physical.	Inorganic.	Mineral.	Organic.	Physiological.	Analytical.	Technical.	Vegetable, Physiology, and Agriculture.	TOTAL.
1872.									
German, ...	41	71	48	296	67	77	138	71	809
French, ...	57	34	16	67	17	19	18	30	258
English, ...	*11+4†	22+6	9+3	13+18	4	33+3	15+2	8	151
Italian, ...	2	1	3	1	...	2	...	2	11
American, ...	3	3	5	1	...	3	...	...	15
1882.									
German, ...	66	66	67	574	88	112	106	209	1442
French, ...	85	58	24	96	13	21	25	35	357
English, ...	60+8	30+21	18+2	31+28	10+8	53+4	25+2	5	305
Italian, ...	...	6	9	54	2	6	3	1	81
American, ...	...	6	7	22	2	9	...	2	48

* Abstracted from other sources than the *Journal of the Chemical Society.*
† Published in the *Journal of the Chemical Society.*

1872, the number of German papers abstracted in the same year was 809. To make the comparison a fair one, we must add to the list of English papers those published in the *Journal of the Chemical*

Society itself, which brings up the total of English papers to 151. Of the papers abstracted no less than 327 were on organic subjects, and of this number Germany contributed 296, England only 31. In 1882, 2,202 papers were abstracted, of which 1,442 were from German sources and 232 from English sources, which, with addition of the papers published in the *Journal of the Chemical Society*,

TABLE III.

Showing the Average Number of Abstracts published in each of the five years of the first and second half of the Decade beginning 1872.

	Physical.	Inorganic.	Mineral.	Organic.	Physiological.	Analytical.	Technical.	Vegetable, Physiology, and Agriculture.
1872-1876.								
German, ...	72	77	88	409	54	100	138	49
French, ...	93	42	24	76	17	26	23	25
English, ...	24	26	17	38	4	32	12	11
Italian, ...	...	4	1	11	...	3	...	5
American, ...	2	2	5	1	...	2	...	...
Russian, ...	...	...	...	...	...	...	...	...
1877-1881.								
German, ...	73	75	81	518	56	133	126	81
French, ...	56	55	22	103	9	24	13	23
English, ...	45	43	16	54	11	53	28	15
Italian, ...	2	4	4	35	2	7	1	2
American, ...	2	3	8	5	...	4	...	...
Russian, ...	...	1	...	5	...	...	...	...

gives an English total of 297. Of the German papers, 574 were upon organic subjects, of the English only 59. Thus, while in Germany the number of papers and memoirs on organic chemistry rose in ten years from 296 to 574, the number of English papers rose only from 31 to 59. The rate of increase has been nearly the same, but the Germans started from a high, we from a very low figure. Table III. gives the average number of abstracts for each of the first five and last five years respectively of the decade beginning with 1872, and, perhaps, affords a fairer view of the progress made within the period than is obtained by contrasting the first with the last year of the decade.

It may be objected to this way of looking at the subject that it tells nothing as to the relative value of the papers. But it must be remembered that the figures we have been considering are based upon abstracts made in England, and therefore, we must suppose, with a due regard to what English chemists are likely to consider important or unimportant.

But, if English editors and abstractors are not above suspicion of partiality where Germans are concerned, Frenchmen assuredly are, and it is interesting to see in what way they regard the subject. For some years M. Wurtz furnished to the *Annales de Chimie et de Physique* abstracts of the more important foreign contributions to chemical science.

Unfortunately, his abstracts cease in 1874, but they come down far enough to enable us to judge of their bearing on the subject. In the year 1870 he abstracted 17 papers, which were all from German sources, and upon organic chemistry; in 1871, 13 papers on organic chemistry, 12 from German and 1 from English sources; in 1872, 28 papers, 27 upon organic subjects, of which 23 were German, 2 English, and 2 Russian; in 1873, 9 papers, all organic, and all from German sources; in 1874, 18 papers, 16 organic, of which 13 were from German, 2 from English, and 1 from Russian sources. These abstracts represent only the most important contributions made to organic chemistry in the years mentioned, and it will be seen that in the opinion of so distinguished a judge—*and he a Frenchman*—as M. Wurtz, out of a total of 81, 74 are German and only 4 English.

In Table IV., which shows the number of abstracts published in the *Berichte der Deutschen Chemischen Gesellschaft* in 1882, we have the German estimate of the importance of the contemporary contributions to the science.

TABLE IV.

Showing Number of Abstracts published in the *Berichte der Deutschen Chemischen Gesellschaft* in 1882. Arranged according to Subject and Nationality of Authors.

	Physical, General, and Inorganic.	Organic.	Analytical.	Physiological.	Total.
German, ...	57	110	116	159	442*
French, ...	149	103	28	23	303
English, ...	57	42	7	61	167
Italian, ...	16	46	2	15	79
American, ...	5	27	1	20	53
Russian, ..	12	28	1	11	52

Before leaving this part of my subject I shall, instead of the abstracts, take as my authority the original literature of the three principal European countries and compare them. For reasons already pointed out, it is not possible to make exhaustive lists; but we may arrive at a fairly accurate estimate by comparing the journals, which occupy relatively the same position in the different countries.

Thus, in Germany the *Berichte der Deutschen Chemischen Gesellschaft*, and in France the *Bulletin de la Société Chimique* occupy respectively the same position as the journal of our Chemical Society. The German *Annalen der Physik und Chemie* corresponds to the physical portion, and Liebig's *Annalen der Chemie* to the chemical portion of our *Philosophical Magazine*, and of the French *Annales de Chimie et de Physique*. The French *Comptes Rendus de l'Academie des Sciences* and the German *Monatsberichte* and *Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin* are respectively the equivalents of the publications of our Royal Society.

Confining our attention, then, to these journals, and omitting all notice of journals devoted to special departments of the science, we obtain the results given in the accompanying Table.

* This total does not include the papers published in the *Berichte der Deut. Chem. Ges.*, for which see Table V.

TABLE V.

Showing Number of Papers on Chemical subjects published in the principal English, French, and German Journals in the two years 1872 and 1882.

Germany.			France.			England.		
	Organic.	Other Branches of Chemistry.		Organic.	Other Branches of Chemistry.		Organic.	Other Branches of Chemistry.
Ber. der deut. Chem. Gesell.	175	80	Bull. Soc. Chim.,	45	24	J. Chem. Soc.,	16	18
Liebig's Ann.,	95	24	Ann. Chim. Phys.	26	25	Phil. Mag.,	2	24
Monats Ber. der Preuss. Akad.,	6	5	Compt. Rend.,	78	70	Phil. Trans. and Proc.,	30	19
Total, ...	276	109		149	119		48	61
			1882.					
Ber. der deut. Chem. Gesell.	460	108	Bull. Soc. Chim.,	38	31	J. Chem. Soc.,	28	37
Liebig's Ann.,	62	11	Ann. Chim. Phys.,	18	18	Phil. Mag.,	0	17
Monats Ber. der Preuss. Akad.,	4	1	Compt. Rend.,	108	165	Phil. Trans. and Proc.,	6	14
Total, ...	526	120		164	214		34	68

These figures confirm on the whole those based upon the abstracts. To make the comparison a perfectly fair one for Germany, the papers published in journals, such as the *Journal für Praktische Chemie*, which have no equivalent either in this country or in France, ought to be added.

With regard to the progress of an important branch of chemistry, of which I have not yet made mention, the "Year Book of Pharmacy" affords valuable information. It gives annually a summary of all the more important contributions made during the year to pharmaceutical chemistry. In 1882 I find that the number of abstracts from various sources, arranged according to nationality, was as follows:—German, 102; French, 43; English, 29; Italian, 9; American, 1; Russian, 6.

According to the *Verzeichness der Bücher*, there were published in 1882, in Germany, 138 distinct works on chemistry, of which 25 were devoted to pharmacy and 38 to organic chemistry. In the same year, according to the English Catalogue, only 18 works on chemistry were published in this country, and of these none were specially devoted to organic chemistry.*

From all the figures which I have brought together, I think two conclusions may be fairly drawn—(1) That this country is far behind Germany, and even France, in the number of its contributions to organic chemistry; (2) that this country does comparatively little in those departments of chemistry in which a knowledge of the allied sciences is involved.

But I do not wish to insist too much upon the mere number of papers. It will naturally be asked, What is the value of the multitudinous contributions made annually by German chemists to science?

This opens up a question of great difficulty. It is impossible to estimate the value of much of our contemporary science, just as it is impossible to estimate the value of contemporary literature and art. It is its influence upon the future development of science that finally determines the value of a scientific theory or the importance of a scientific fact, and of this we cannot judge. In endeavouring to form an opinion as to the value of scientific

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* For much valuable aid in the preparation of the statistics upon which this paper is based, I have to acknowledge my great indebtedness to Mr. G. G. Henderson, B.Sc., of the Chemical Laboratory, University of Glasgow.

research, it must be borne in mind that investigations may, with more or less accuracy, be divided into two classes:—

(1.) Those that employ known methods, and proceed upon known theories or hypotheses. This is the kind of research, and the only kind of research, that can be directly endowed. It can be bought as any other kind of service can be bought. Its market value is perfectly well known.

(2.) Those that employ new methods, or which proceed upon new theories or hypotheses. To attempt to endow this kind of research, unless the endowment takes the form of reward for work already accomplished, is to incur a very great risk of endowing idleness.

Those who engage in the former kind of research require only a knowledge of the principles of the science and manipulative skill; those who engage in the latter must, in addition to these qualities, be possessed of originality. The former class of investigators derive importance only from the practical results of their work; the latter class, although their work may fall far short in immediate practical results of that of the other, have their merit irrespective of this altogether. The former class may claim the name of investigator; it is only to the latter that the name of original investigator belongs.

Now, it seems to me that it is the constant confusion of these two classes with one another that has brought research in certain quarters into disrepute. It is the claim for all research of the merit and the reward which should be reserved for original research, that has caused many to undervalue altogether research which is not original.

But admitting, for the sake of argument, that by far the larger number of the German researches belong to the first of the two classes indicated, are they therefore useless? I think not. They are hardly ever without some positive result, which adds something, however little, to the store of our knowledge. And surely such contributions to science, however humble, are valuable. Why should we despise the chemist who devotes himself to the preparation of series of salts or ethers, and to the accurate determination of their melting points or boiling points, because we know from analogy what compounds are likely to have an existence and what their properties are most likely to be? The astronomer can calculate with utmost nicety the movements of the heavenly bodies, but he does not on that account fail to use every opportunity of verifying

his calculations by actual observation. Scientific men forfeit their title to the name when they take for granted the simplest fact, which is capable of experimental verification.

Researches which are not original may be defended on many grounds.

Without them chemistry could not progress, for of this science more than of any other are the words of the Laureate true—

"Science moves, but slowly, slowly, creeping on from point to point."

The accumulation of littles has done not less to promote her progress than the discoveries and generalisations of her greatest masters. Indeed, without the constant accumulation of facts by the humbler workers in the science, the generalisations would not be possible.

But, say some, at least let the researches, if we must have them, be practical in their end, let them be devoted to some purpose which is obviously directly useful. This unfortunate misunderstanding as to what is useful has done more than anything else in this country to discourage and repress research. If scientific inquiry were limited to that which has a directly practical bearing, progress would necessarily speedily come to an end. Particular manufactures might no doubt benefit for a time, from concentration of all attention upon their details, but even here, when the need arose for a new principle, progress would be arrested. All our manufactures are based, more or less, upon the accumulated experience and research of past time. We have come into a rich inheritance. We must take care that we pass it on to those who come after us, not only undiminished but increased. We have no more right to use up the research and experience of the past, without doing something to renovate and increase the store, than a farmer has to exhaust the virgin soil, or a wood-man to cut down the forest primeval, without regard to the future. It is just as shortsighted and foolish a course in the one case as it is in the other. Yet this is, in effect, what we do if we give way to the demand for technical education, as understood by many at the present time. What is a limiting of the education of our chemists, strictly to the requirements of our present manufactures, but an exhausting of the stored-up capital of the past for present purposes? There can be no doubt that the chemical industries of this country have suffered grievously even in our own time from want of research. In the older manufactures we perhaps hold our own, but in all those industries which

involve the application of recent developments of pure chemistry, we are behind, and must remain behind until we recognise the need for higher and wider teaching. And even in old industries, so long as there are waste products, there must be room for improvement. Nature has no waste products. By ceasing too soon to speak of the wonders of nature, and by learning too soon to boast of the achievements of science, we have lost many of the lessons which the majesty and perfection of the operations of nature are fitted to teach.

Others, who recognise the practical value of research, say, let the plodding German work out the details of organic chemistry, and then we with our superior practical genius, and our unlimited capital, will step in and help to reap the harvest he has sown. Experience has proved that such a policy is as futile as it is selfish. Results may be borrowed, but not the practical skill and experience which have been accumulated during the slow process of working out the results. Consider the cases of the aniline dyes, of alizarine, of indigo, to which I shall refer more particularly by-and-by. Why, although we know all the mysteries of its production, has the manufacture of alizarine never flourished in this country? There is but one answer—because this country does not possess the necessary scientific skill, and our manufacturers are not yet sufficiently alive to the importance of wide scientific as opposed to narrow technical education. They defeat their own end by too constantly aiming at results which shall immediately yield practical fruits. Look at other sciences, and see how they are dependent at every step in their most practical aspects upon previous work, done without reference to practical ends. See what the physicist owes to the mathematician. No doubt a great physicist sometimes devises his mathematical methods to meet the exigencies of his research; but it is oftener the other way. Take the case of the Harmonic Analysis of Delambert and Fourier, with its innumerable applications to the theory of waves; to the theory of elastic solids; to the undulatory theory of light; to the theory of sound, and to such practical purposes as the calculation of tides, and the calculation of the semicircular and quadrantal errors of the compass. Or consider how the wonderful electrical applications of the present day depend upon past research. When Galvani experimented upon the frog, I do not suppose he dreamed of the electric telegraph. Faraday's experiments were avowedly conducted

without reference to practical application, yet to what man in the whole range of science more than to that great experimenter do our industries and our commerce stand more indebted at the present day? The researches of that chemist of whose connection with this city and society we are all so proud, and which we are about to celebrate in a few days, are every day receiving new applications in the arts. Their influence upon the solution of practical problems both of vegetable and animal physiology has been incalculable, yet to Graham they were investigations of natural laws, investigations in the domain of pure science.

I speak from a broad—from a national point of view. I do not say that it is for the manufacturer individually to engage in experimental researches not bearing directly upon his own manufacture, in the hope that he may ultimately benefit by them. I do not say that it would be for his advantage to prefer chemists with a large theoretical knowledge and liberal education to men who have special knowledge of, and skill in, the manufactures in which he is engaged. What I maintain is, that it is for the benefit of the country as a whole, for the benefit of its manufactures as a whole, in revising our schemes of national education, to aim, not at fitting a man for this or that manufacture, but at providing him with a wide and general education, and at teaching the principles of science which lie at the root of all applications.

This brings me to a second argument in favour of the extension of original research.

Our manufactures require a large body of trained chemists. What better training could there be for them than engaging in that sort of research to which I refer? And thus a twofold end would be gained; the bounds of science would be made wider by the results of their labours, and the education of our chemists would be rendered more complete, and the chemical industries of the country benefitted.

But, passing from these general grounds, I desire to make my argument as practical as possible. Before further urging the extension of research as both an end in itself and a means of education, I wish to show more particularly the practical value of such researches, measuring value by the standard, which everyone understands—of pounds, shillings, and pence. There are two ways in which I might attempt to do this. I might trace some discovery from its beginning to its practical issue, or I might trace back some discovery of admitted practical value to its origin, and

show upon what previous discoveries it rested, and how, without them, it would have been impossible.

I prefer the latter method, and for my purpose I shall select a discovery with which everyone is familiar; I mean that of artificial alizarine.

The earliest patent of the discoverers of the method of synthesising this substance says:—"Pure anthracene is converted into anthraquinone by one of three methods. * * * The anthraquinone obtained is converted into dibromanthraquinone by heating one equivalent of anthraquinone and four equivalents of bromine in closed vessels for several hours to the temperature of 80°–130° C. The dibromanthraquinone is then heated in closed vessels, with concentrated soda or potash-lye, to 180°–260° C., in order to replace the bromine with hydroxyl. The mixture slowly assumes first a blue and then a violet colour, which gradually becomes more intense. When the depth of colour no longer increases, the mass is allowed to cool, dissolved in water, filtered, and supersaturated with sulphuric or hydrochloric acid, when alizarine separates out in yellow flakes, which are filtered and purified by washing with water."* How simple all this appears to those who are acquainted with the reactions of organic chemistry, yet of what an amount of work is it the outcome! Let us see upon what researches this most practical discovery rested.

Graebe investigated the chemical composition of a substance known as quinone, and succeeded in showing that it is closely related to benzol. This research had no reference whatever to alizarine. The discovery of the relation between quinone and benzol suggested to Graebe that other substances might stand in the same relation to other hydrocarbons. About that time a compound known as chloride of chloroxynaphthyl was attracting much attention on account of its supposed relation to alizarine, and Graebe was led to suspect that this body might be the dichlorinated derivative of a substance (a quinone) related in the same way to naphthaline that quinone is to benzol. This surmise proved to be correct, and thus the word quinone, as so often happens, came to be the name of a class of substances. The reason for suspecting a connection between alizarine and chloroxynaphthalic acid was that both substances, when decomposed by nitric acid, yielded the same product—viz., phthalic acid.

* Crookes' "Practical Handbook of Dyeing and Calico-Printing," p. 223.

Bichloronaphthoquinone, when heated with caustic alkali, gave a salt, the acid of which was supposed to be chlorinated alizarine.

These discoveries suggested to Graebe and Liebermann that alizarine might be of the nature of a quinone. The question to be settled was, to what hydrocarbon was it related? To discover this the experimenters made use of a method of investigation discovered by Baeyer, the synthesiser of indigo—viz., distillation with zinc dust, and they found that when heated in this way alizarine yielded a hydrocarbon similar in all respects to the anthracene got from coal tar. Having got from alizarine to anthracene, all that remained to be done was to get back again from anthracene to alizarine.

Before Graebe and Liebermann's time, Laurent had discovered a substance to which he gave the name of anthracenuse. This substance was examined by Dr. Anderson, who assigned to it the formula $C_{14}H_8O_2$. Graebe and Liebermann recognised in anthracenuse the quinone of anthracene. If alizarine was really the *quinone acid* of anthracene, all that was required to convert anthraquinone into alizarine was to substitute two atoms of its hydrogen by hydroxyl. Here, again, they availed themselves of a previous discovery. It had been proved that chloranil, when treated with caustic potash, gave chloranilate of potash. Dibromanthraquinone treated in the same way gave an alkaline solution of alizarine, from which, when acidified, a yellow precipitate of alizarine was obtained, and thus the discovery was completed.

At every stage this discovery rested upon previous researches, undertaken with a totally different object. It rested immediately upon five previous discoveries, without any one of which the synthesis could not have been accomplished.

(1) The discovery of the nature of the quinones.
(2) The discovery of the relation of alizarine to anthracene, employing Baeyer's method of investigation.
(3) Discovery of the relation of naphthaline to oxynaphthoquinone.
(4) Laurent's discovery of anthracenuse.
(5) Discovery of the action of caustic potash upon chloranil.

And each of these five discoveries in turn rested upon innumerable previous researches, which had no reference to the synthesis of alizarine.

Here, then, is a most practical discovery resting upon a whole

series of researches, nearly all carried out on the Continent, without having any immediate practical aim. I prefer it to all others for my purpose, because alizarine is a substance with which, in this district, we have so much to do—everything to do except its manufacture.

I do not think that it is a wise or thrifty policy for a nation to seek to produce and to manufacture everything that it needs for its own use. Natural conditions will often give to one country advantages which another does not possess for the growth or manufacture of certain products. Why, then, should that country struggle against the hand of nature, and not rather avail itself of those advantages which it is certain to possess in other directions.

But no natural causes forbid us to make alizarine. On the contrary, we have apparently everything in our favour. One of our chemists bore a distinguished part in the discovery. We possess the crude material and export it for others to manufacture. We import the finished material; we use it largely in our print-works. We possess every advantage for the manufacture of the article but one—we want the skill. Surely this is a matter of reproach to us. Only a few days ago in this city Mr. Mundella said, "Take the waste products of our gas-works, which were originally utilised at home. I am told that the waste products of the gas-works in England are sent to Germany, where they are treated by German chemists and come back to us in the shape of aniline dyes and other materials to the extent of two millions sterling." According to Professor Roscoe, in 1880 the estimated production of artificial alizarine was 14,000 tons (containing ten per cent. alizarine), the value of which was estimated at £1,568,000 or £122 per ton. According to the same authority, the total annual value of coal tar colours is 3½ millions sterling; and England, while furnishing all the crude material, and using a very large proportion of the manufactured product, makes only a small fraction of the colours.

Equally instructive with the discovery of the original method of manufacturing alizarine, is the history of the modification afterwards introduced simultaneously by Mr. Perkin in this country, and Graebe and Liebermann in Germany. It was my intention, had time permitted, to have sketched the history of the synthesis of Indigo, and shown how at every stage the discovery rested upon previous discoveries made without immediate practical aim. And numerous other instances might be given.

Liebig in one of his letters on chemistry says, "The chemist

produces the crystalline substance found in the fluid of the allantois of the cow from the excrement of snakes and birds; he makes urea from charred blood; formic acid and oxalic acid from sawdust; the volatile oil of *Spiraea almaria,* of *Gaultheria procumbens* from willow bark; the volatile oil of Valerian from potatoes. These results are enough to justify us in entertaining the hope that we shall ere long succeed in producing quinine and morphine and those combinations of elements of which albumen and fibrine or muscular fibre consist, with all their characteristic properties." *

Liebig's prophecy bids fair to be fulfilled. Some years ago I had the honour, along with Principal Ramsay of Bristol, of discovering a reaction which, according to one of the highest continental authorities, was the first to establish a connection between quinine and bodies of a simpler constitution.† The work which we commenced has passed entirely into German hands. Hosts of chemists attacked the problem as soon as the clue had been found. Every day progress is being made towards the unravelling of the constitution of quinine, and probably some here to-night will live to see the manufacture of quinine and morphine carried on like the manufacture of alizarine.

But the glory of discoveries which will enrich science, and confer a boon on all mankind, which will bring wealth and lasting fame to all who have part in them will, like the glory of the synthesis of alizarine and indigo, pass to a foreign country.

What, then, is responsible for the backward condition of chemistry in this country, and what is the remedy?

I have shown that, during the last ten years, even research has made steady if tardy progress; that numerous societies, having for their object the improvement of chemical education or the advancement of certain branches of the science, have arisen; and that many new colleges have been founded.

But while there has been increase in the number of teachers, almost nothing has been done in the way of differentiation of the teaching.

The bounds of the science have been widened so that it is no longer possible for one man to be acquainted with the whole range of the subject; yet little or no effort has been made to separate the teaching of the different branches.

The Owens College is, I believe, the only institution in the country which has even a separate Professor of Organic Chemistry. I

* Familiar Letters on Chemistry, I.
† *Königs. Berichte der Deut. Chem. Gesell.*, 1879, p. 97.

do not say that to this fact is to be attributed the celebrity and influence which that school of chemistry has acquired, but obviously it has contributed to it.

It is not to be expected that the newer colleges should be able to support more than one teacher of chemistry. They must have time given them to discover in what directions they can most profitably develop. But it is unfortunate that in our older colleges and universities so little is done to keep pace with the rapid progress of the science. While the applications of chemistry have been extending in every direction, and there is hardly a single city in one of our great centres of population which is not to a large extent dependent upon manufactures in which chemistry is principally concerned, nothing has been done to bind closer the ties between the Universities and the great practical life of the people. Hence the sympathy of the public—at least of practical men of business—has been alienated from our older seats of learning. They see that, while every second factory calls for a man educated in chemistry, the Universities continue to teach it as it was taught when it had importance only as a branch of medicine. They see that the educated chemist must be sought for abroad, and that the education which shall enable their sons to carry on their business with intelligence can only be had abroad.

But those who condemn our Universities forget too often that the fault does not lie altogether with them, but with Government, which, with ill-judged parsimony, refuses the necessary funds, and denies to local institutions that elasticity and adaptability to altering circumstances which is its own most marked feature. Acts of Parliament are needed to effect the changes which are so necessary, but Parliament is too busy to pay attention to such matters; and, when it does interfere, it is unfortunately too often only to alarm and agitate by the threat rather than the promise of coming legislation.

It is certainly to be deplored that while it has done so much to encourage, not always wisely, elementary scientific education, our Government should be so slow to recognise the great public benefits which our Universities might confer if only they received proper encouragement.

That there are objections to the multiplication of the teachers of one science in the same University cannot be denied. But what is wanted is not several teachers of the same subject, but teachers of the special branches of each great subject.

By such an arrangement the unity of teaching could not seriously suffer, and such rivalry and competition as might arise could only be of a wholesome kind. But even granting that under such conditions different views of the same subject might be promulgated within the same University, that would not necessarily be a misfortune either for science or for the University. It is not desirable that one point of view should always be preserved, especially in the teaching of such subjects as are progressive. The development of scientific theory takes place through diversity of view. It rarely happens that one mind, however keen and subtle, can give perfect shape and consistency to a new idea. This is attained only through the modifying process of opposition. Wurtz, in his *History of Chemical Theory*, referring to the opposition offered by Berzelius to the theory of substitution, says:—"The great discussion has borne fruit, and the violent opposition of Berzelius has been more salutary than silence and repose could have been. Thus, after having so greatly honoured science by his discoveries, this powerful contradictor has also served it by his errors; such is the beneficent power of work."* Limit for any length of time the teaching of a subject to one man, and however active in his intellect, however industrious in his effort to keep abreast of the times, however quick to grasp new ideas, he will inevitably fall behind his age. For a while the natural elasticity of a great mind may keep it abreast of the times, but when the elasticity is gone the very strength of intellect which gave consistency to his ideas becomes fatal to their further development, and the progress of the science is arrested during his lifetime. Although few institutions can boast of so unbroken a succession of able and distinguished teachers as the Scotch Universities, it has happened again and again in the course of their history, that during the lifetime of the only person authorised to teach a subject, that subject, from one cause or another, has remained practically untaught, and a grievous injury has been inflicted upon several generations of students.

Looking to all the circumstances, surely more is to be gained than lost by having all branches of learning, where the extent or importance of the subject renders it desirable, represented by more than one teacher.

> "Two plummets dropped for one to sound the abyss
> Of science."

Until we have this, it is vain to think of attempting to cope with

* Wurtz' *History of Chemical Theory*, Watts' Translation, p. 82.

foreign Universities, where thorough subdivision of labour enables the teachers to work out the details of every branch of the science, while our most eminent men are forced to go over the same ground year after year; always repeating the elements of the subject, never advancing beyond them. It is vain to expect men who are required to teach what in other countries is distributed amongst half-a-dozen teachers to rival those teachers, or to create schools equally efficient and celebrated.

It is not for me to say in what way the changes that are necessary should be effected. They should be effected not without due regard to the position and privileges of present teachers, and not without regard to the special needs of each town and the traditions of each University. Unless some power of adjustment is given to the Universities themselves, it seems to me that any improvement can only be of a temporary and entirely insufficient nature. An obvious method of dealing with the difficulty in Scotland would be to strengthen the Courts of the Universities, assimilating them more and more to the Councils of the recently-founded Colleges, entrusting them with such powers as would obviate the necessity, every time altering circumstances demanded slight changes, for calling the whole legislative machinery of the State into operation.

What we need in this country is the creation of schools of chemistry, in which, as in the great Universities of the Continent, every branch of the science should be taught, which should possess ample laboratories, thoroughly equipped for the prosecution of research.

What is the consequence of our neglect of the higher branches of chemistry? Our students go abroad to receive their education, or, if they remain at home, receive an education which, so far as theoretical training is concerned, is limited to the rudiments of inorganic chemistry, and, so far as practical work is concerned, is limited to a merely analytical training. In Scotland we see with indifference, and even with complacency, our best students repair to the English Universities for that education in classics, literature, and mathematics which our own Universities ought to afford them. But the case is worse with our science students. They cannot get the education they require even in England, and are forced to seek it abroad in the laboratories of Germany or Switzerland.

Still our Universities make no movement. Cambridge and even Oxford have begun to bestir themselves, and now offer great

inducement to students of science, and probably we shall soon see our best students resort thither for natural science, as they do at present for Classics and Mathematics.

In the case of the older learning the rich patronage, rather than the superior training, may be alleged as the cause which draws our students to the south. Science needs no such patronage. If our Universities provide the proper training, our manufacturers will prove more munificent patrons than the Church or the Colleges.

We constantly hear of the industries of this country being supplanted by those of the Continent. There is one industry which has certainly passed completely from us, the industry of higher teaching. It is surely a disgrace to this country that there are at this moment in the continental schools, a number of English students sufficient to maintain several thoroughly equipped schools of chemistry.

The cause of the backward condition of chemistry in this country is plain; it is want of teaching. The remedy is plain; provide more teaching; encourage research. It will pay twice over. It will benefit our manufactures. It will, provide a body of skilled chemists throughout the country. It will by increasing the number of students, increase the number of professional chemists upon whom the progress of the science is in every part of the world so largely dependent.

I have spoken of practical researches, and had intended to say something upon the value, even from a practical point of view, of theoretical researches in chemistry, and of the great need of encouraging them in this country. Chemical theory is in anything but a satisfactory condition. Look, for example, at our chemical equations, which are every day becoming more and more discredited, and to which slavish adherence, and of which ignorant use, have sometimes led to disastrous results. There is a great field for useful research to supply the experimental data whereby the present statical may be replaced by dynamical equations. The mischievous and misleading use of structural formulæ, too, urgently calls for correction. In Germany, even more than in this country, the abuse of the theory of the Benzol ring, and the method of representing the relation of the isomeric series of aromatic compounds to one another, is rapidly degrading organic chemistry from the position of a science to that of a mere mechanical puzzle.

The second great want which the statistics given at the outset revealed was a want of such researches as involve a knowledge of

more sciences than chemistry. Take up any recent text-book of Physiology or Agriculture, or of any science which is at all dependent for its progress upon chemical research, and you will find that nearly all recent advances have been achieved by foreigners. The reason of this is obvious. Chemists abroad are trained in the Universities and receive a liberal education, and many of them acquire the requisite knowledge for the prosecution of researches of this class. With us a chemist seldom seeks the University, but picks up his knowledge wherever he can, and only rarely travels beyond the domain of his own science. The remedy in this case is the same as in the case of organic chemistry. We must provide a more liberal education for our chemists.

We have been accustomed for many years to the cry that continental manufacturers are beating us out of all the markets, and the answer this country has given is the appointment of the Chemical Commission. With regard to much of the outcry I feel inclined to quote the words of one of our most eloquent writers:—"Happy is that people whose commerce flourishes in ledgers, while it is bewailed in orations, and remains untouched in calculation, while it expires in the pictures of eloquence." But with regard to one class of manufactures the cry is but too amply justified; I mean those manufactures that involve the application of chemistry.

What, then, is the cause of this? Is it that our countrymen do not possess the necessary talent and genius? Surely not. Look back upon the history of chemistry for the last hundred years, and I think we can show as proud a list of illustrious names as any nation. In such matters we must take wide views, we must not confine ourselves to any short interval of time. But who will venture to say that there are not even now in this country men whose names will rank high in the history of the science? It is not when the picture is fresh from the hand of the painter, and the disputes of schools rage round it, that its true worth can be estimated. So it is with our great men. It is only when placed in the long gallery of time, and when seen by the sober light of ages, that their proper place in history can be assigned. Assuredly the chemical genius of this country is not now, if I may be allowed to use a chemical illustration, a mere *caput mortuum* from which all that was valuable has been distilled away.

It is not in original minds, it is not in original investigators that this country is deficient, but in that other class of more laborious investigators, upon whom science is no less dependent for its advance.

I have endeavoured to point out the remedy for our defects. Possibly it would have been applied long ere this, had it not been that it has been too often sought in the wrong direction. The association of the perfection of continental manufactures with an elaborate system of technical education has led people in this country to assume that in every case in which we are inferior our inferiority must be due to the want of technical education.

Granting that in other branches of industry, whatever they may be, technical education is to have the credit, assuredly it is not entitled to it in the case of chemistry.

The great schools of chemistry in Germany are within the Universities. The great discoveries in chemistry have been made, not in the technical schools but in the Universities, and by men who have been trained in the Universities. The large number of educated chemists employed in the great chemical works throughout Germany are supplied, not by the technical schools but by the Universities. Our students when they go abroad to study chemistry, repair not to the technical schools, but to the Universities. And I believe that the superiority of the German chemist over other German manufacturers is in great measure due to this fact, that he has been trained in the Universities, which are the least German of all German Institutions. The characteristic of their schools, of all branches of their public service, is uniformity, routine; the characteristic of their Universities is freedom—freedom to the teacher, and freedom to the taught.

If, then, we wish to emulate the Germans, we ought to educate our chemists with the same liberality, not necessarily in Universites, but where they will receive an education as broad and as thorough as that which they receive in the German Universities. If our Universities will not or cannot do this for them, let us have Institutes like that of Prof. Fresenius in Wiesbaden.

But do not let us be led away by those who would have us believe that the Science and Art Department does all that is required. It does good where it does not interfere with the ordinary school education of the country, but its work is almost entirely elementary; and while it does much to spread a knowledge of chemistry amongst the people, it does almost nothing for the progress of the science. Do not let us, on the other hand, be led away by those whose narrow and contracted notions would lead them to prefer a technical to a scientific education.

I have argued chiefly from the practical point of view: I

might have taken higher ground. We spend annually vast sums of money in promoting the study of languages and literature. These are cultivated entirely for the value which they are supposed, and rightly supposed, to possess in themselves.

Is chemical science then less worthy of cultivation for its own sake? Surely it is one of the best of all instruments of education, and one of the noblest of all studies, as well fitted to train the mind and to refine the intellect as the study of any branch of art or of literature.

XVI.—*Notes on the Analysis of Commercial Carbonate of Potash.* By Robert Thomson.

[Read before the Chemical Section, 14th January, 1884.]

The subject of this short paper, as announced by the billet, is "Notes on the Analysis of Carbonate of Potash," but to-night I intend to confine my remarks to the methods of reporting one or two of the impurities generally present in commercial carbonates.

The impurities generally met with are chlorine, sulphuric and phosphoric acids, silica, alumina, oxide of iron, and soda, and it is to the first and last of these—chlorine and soda—and their state of combination, that I wish to direct your attention in this short communication.

In the analysis estimations are made of potash, chlorine, sulphuric and phosphoric acids, alkali, silica, alumina, and oxide of iron, insoluble matter, and moisture. Regarding the processes to be used in estimating these substances, I do not suppose there is much diversity of opinion, with one exception perhaps—the potash—but I believe from time to time controversies have arisen among chemists as to the manner of reporting some of the impurities. Some analysts calculate the chlorine and sulphuric acid found to sodium salts, this, I have been told, being often done in Germany, and I know of two English chemists who report in this way. Others, going on the assumption that the strongest acids are combined with the strongest bases, report these impurities as sulphate and chloride of potassium, this being the custom in the City Analysts' Laboratory here.

The following are the methods of calculation and form of report there in use:—To the sulphuric acid, chlorine, and phosphoric acid are allotted their respective quantities of potash, the rest of the potash being calculated to carbonate. The potash as carbonate, and, when litmus is used in estimating the alkali, two-thirds of

that combined with the phosphoric acid, is deducted from the total alkali, the remaining alkali being calculated to sodium carbonate. The other impurities are simply brought to per cent. The form is:—

Carbonate of Potash, ...	per cent.
Sulphate of Potash, ...	,,
Chloride of Potassium, ...	,,
Phosphate of Potash, ...	,,
Silica, Alumina, and Iron Oxide, ...	,,
Insoluble Matter, ...	,,
Moisture, ...	,,

When the carbonate of potassium leaves the furnace there will often be a small quantity of sulphate left unreduced, which will account for the presence of sulphuric acid, but with the chlorine the case is different, the greater portion of this impurity being sometimes intentionally introduced in the form of sodium chloride. Owing to the fact that there is some difficulty in getting a higher price for, say 93 or 95 per cent. carbonates than for those containing only 90 per cent. carbonate of potassium, some manufacturers are in the habit of adding common salt in order to reduce them to the standard figure—90 per cent.—in cases where the strength is much above that. This not only lowers the percentage of carbonate of potassium, but, as I propose to show, destroys a portion of it, forming chloride of potassium and carbonate of sodium.

Recently I heard of a case in which great objection was raised to the form of report used by Mr. Tatlock, and the results of the following experiments were brought forward as proof that that method of reporting carbonates was wrong:—

Equivalent quantities of carbonate of potassium and chloride of sodium were dissolved in water, the solutions mixed, and the alkali neutralised with diluted sulphuric acid. The solution was evaporated, and a crop of crystals separated, the composition of which was said to be pure, or nearly pure, sulphate of potassium. Like quantities of carbonate of sodium and chloride of potassium were treated exactly as above, the crystals obtained here being said to consist of practically pure sulphate of sodium. The experimenter apparently wished to show that in the one case the carbonate of potassium and in the other the carbonate of sodium was simply

neutralised by adding the sulphuric acid, and that no further action took place.

It was after hearing of this that I was asked by Mr. Tatlock to undertake a few experiments, and try if possible to ascertain whether the chlorine remained in combination with the sodium, or formed chloride of potassium, with production at the same time of carbonate of sodium.

1. For this purpose I took carbonate of potassium and chloride of sodium in their equivalent proportions, dissolved them, and mixed the solutions in a large basin. The solution was evaporated till crystals began to form, when the heat was withdrawn, and the basin and contents allowed to cool. A large crop of crystals separated, from which the mother liquor was run off, after which they were quickly washed with cold water, strained as free from liquid as possible, then dried between folds of blotting paper. Of the salts so dried I selected a fair sample, from which the water was entirely removed by heat. On analysis, the following was found to be the composition:—

Chloride of potassium, ...	91·2	per cent.
Carbonate of soda, ...	8·6	,,
Not estimated, ...	·2	,,
	100	

If the alkali be calculated to carbonate of potassium, 11·2 per cent. is obtained; but even though that salt were present, there still remains 79 per cent. chloride of potassium.

2. In order to find out whether the results were similar when carbonate of sodium and chloride of potassium were used, like quantities of these two salts were treated exactly as in the previous experiment. After drying as before, the crystals got in this case gave the following figures:—

Chloride of potassium, ...	68·8	per cent.
Carbonate of sodium, ...	30·8	,,
Not estimated, ...	·4	,,
	100	

When the alkali found here is calculated to carbonate of potassium it gives a percentage of 40·2, but that it is carbonate of sodium and not carbonate of potassium is, I think, proved by the

following experiments:—A quantity of the crystals was dried, first in the water bath, then by gentle ignition, and the weight noted. The capsule containing the dried salts was left freely exposed to the air, and, after several days, the increase in weight observed. This was found to be not more than 3 per cent. A mixture of 60 per cent. of the chlorides of potassium and sodium, and 40 per cent. of carbonate of potassium, when similarly exposed for the same length of time, increased in weight to the extent of 21·8 per cent. I show samples of the salts got in experiments 1 and 2, which have been lying in the open air of the laboratory for a week, and instead of any appearance of deliquescence, there is abundant indication of efflorescence in both specimens.

The following two experiments are repetitions of those mentioned near the beginning of the paper, and I may state they were done at the request of the objector to Mr. Tatlock's method of reporting there referred to:—

3. Carbonate of potassium and chloride of sodium, as in my first experiment, were dissolved, the solutions mixed, and the whole neutralised with dilute sulphuric acid. The solution was evaporated till crystals began to form, when it was allowed to cool. The mother liquor was decanted off, and the crystals quickly washed with cold water, after which they were dried. On examination they were found to be the double sulphate of potassium and sodium (K_2Na2SO_4), the so-called "plate sulphate" of commerce. The composition was as follows:—

"Plate sulphate,"	95·5	per cent.
Sulphate of sodium,...	3·4	,,
Chloride of sodium,...	·9	,,
Not estimated, ...	·2	,,
	100	

4. A result almost exactly similar was obtained by using carbonate of sodium and chloride of potassium, neutralising the mixed solutions, and so on, going through the same operations as in the above experiment. The salt obtained gave on analysis:—

"Plate sulphate,"	95·3	per cent.
Sulphate of sodium,...	3·1	,,
Chloride of sodium,...	1·3	,,
Not estimated, ...	·3	,,
	100	

The results of these experiments, I think, throw a little light on the question at issue. It is pretty evident that when carbonate of potassium and chloride of sodium come together in solution double decomposition takes place, the strong acid combines with the strong base, leaving the weaker acid to combine with the weak base. I believe that in different experiments with these two salts the crystals got by evaporation will vary as to the percentage of chloride of potassium and carbonate of sodium according to circumstances. What these circumstances may be I am not prepared to say, but I think it likely that the degree of concentration of the solution when the evaporation is stopped may have some effect. Lately, when I began these experiments, I obtained, on evaporating a mixed solution of the salts, crystals which contained 31·7 per cent. carbonate of sodium. These had merely been dried between folds of blotting paper, and after standing for an hour the alkali was estimated. On longer standing, the bulk of the crystals began to effloresce, and judging from my other experiments, I am of opinion that they consisted of crystallized carbonate of sodium and a little chloride of potassium. They were mislaid, however, else I would have made a more complete examination of them.

In experiment 1 the evidence in favour of the theory that the strong acid unites with the strong base is pretty conclusive, as when looked at in its most favourable aspect the analysis shows 91 per cent. chloride of potassium in support of it; and even taking the worst view of the case, there still remains 79 per cent. of the chloride. The presence of carbonate of sodium is, of course, just as good proof that double decomposition has taken place as the presence of chloride of potassium. In the second experiment, were it not certain that the alkali exists as carbonate of sodium, the evidence would not be so strong, but even at the lowest estimate there is no denying that there is 25 per cent. of chloride of potassium present. A small quantity of chlorine is reported in analyses 3 and 4. Whether this is combined with potassium or sodium would be very difficult to decide, as, owing to the sulphuric acid being combined partly with the potassium, partly with the sodium, there must necessarily be a quantity of both chlorides in in solution. This, however, is a matter of little consequence. These two experiments were intended by their proposer to prove that when a solution containing carbonate of potassium and chloride of sodium is neutralised with sulphuric acid, pure sulphate

of potassium separates on evaporation, and pure sulphate of sodium, when carbonate of sodium and chloride of potassium are similarly treated. From these results one is expected to infer that carbonate of potassium and chloride of sodium do not react on one another in solution. My experiments, as I have shown, do not confirm the production of the pure sulphates under these circumstances, as "plate sulphate" was obtained in both cases.

XVII.—*A New Process for the Separation of Nickel and Cobalt.* By JOHN CLARK, Ph.D., F.C.S., F.I.C.

[Read before the Chemical Section, 26th November, 1883.]

IN 1879 Dirvell published a process for the separation of Nickel and Cobalt (*Chemical News*, vol. xl., p. 268), based upon the precipitation of the cobalt as ammonio-cobaltic phosphate, by means of microcosmic salt and bicarbonate of ammonia, prepared by saturating effloresced carbonate of ammonia with carbonic acid till all ammoniacal smell is gone. In carrying out the process he adds to an aqueous solution of the nitrates or sulphates of cobalt and nickel a quantity of cold saturated solution of microcosmic salt equal to 30 times the weight of the two metals, and a volume of bicarbonate of ammonia equal to that of the microcosmic salt. The mixture is slowly heated till the equivalent of carbonic acid in excess escapes, ammonia is then added to dissolve the precipitate, and the solution is heated till the ammonio-cobaltic phosphate separates as a precipitate of a beautiful purple colour, inclining to violet, which is found by analysis to have the following composition:—(NH_4O, $2CoO\ PO_5 + 2HO$) = $Co\ NH_4\ PO_4 + H_2O$—and by ignition is converted into pyrophosphate of cobalt $Co_2\ P_2O_7$. The nickel remains in solution, communicating to it a clear, blue colour, and is only precipitated after protracted boiling. Dirvell states further that M. Pisani, in whose laboratory the experiments had been made, had found that acetate of ammonia could be used instead of the bicarbonate of ammonia, and he gives certain directions for ascertaining approximately the proportions of cobalt and nickel from the colour of the solution.

So far as I am aware, Dirvell has not published any of the results which he obtained by this method, and in endeavouring to carry out the process in the manner described I found that when microcosmic salt and bicarbonate of ammonia were employed, it was very difficult to precipitate the whole of the cobalt, or some-

times even to precipitate a portion of it. With the acetate of ammonia and microcosmic salt the process worked better, but still unsatisfactorily. It appeared to me, nevertheless, that the process might be improved, and with that object I made a number of experiments, in the course of which I found (1) that phosphate of ammonia was the most suitable substance for precipitating the cobalt, but ordinary phosphate of soda can also be used; (3) in estimating the cobalt it is not necessary to use bicarbonate of ammonia or acetate of ammonia, as chloride of ammonium, nitrate of ammonia, and sulphate of ammonia do equally well with the acetate, and better than the bicarbonate; (3) in the case of phosphate of ammonia, it is only necessary to use a little more than what is theoretically required to precipitate both cobalt and nickel as phosphate, but when phosphate of soda is employed a much larger quantity is necessary; (4) I can confirm the correctness of the formula given by Dirvell to the ammonio-cobaltic phosphate and pyrophosphate of cobalt.

Process.—In separating cobalt from nickel I proceed as follows: —The solution containing the two metals in the form of chlorides, nitrates, or sulphates is mixed with an excess of phosphate of ammonia (about 5 times the weight of the combined cobalt and nickel is amply sufficient), and for every part of phosphate of ammonia about 5 parts of ordinary hydrochloric acid are added, and the mixture is boiled for several minutes, to make sure that all the phosphoric acid is present as ortho-phosphoric acid. The beaker or other vessel is then removed from the flame, and while still nearly boiling ammonia is added cautiously in small quantities at a time till the precipitate which is at first produced redissolves. The solution is then stirred vigorously for about a minute, when the cobalt will separate out as a fine purple crystalline powder, consisting of ammonio-phosphate of cobalt. About 10 drops of ammonia are then added, and the beaker placed for a few minutes on the top of a water bath. When the precipitate has settled it is thrown upon a filter, washed with cold water, then ignited and weighed as pyrophosphate of cobalt ($Co_2 P_2 O_7$), containing 40·4 per cent. of cobalt. The filtrate from the cobalt will be more or less of a clear blue colour, the intensity of which will depend on the quantity of nickel present.

As the filtrate generally contains a small quantity of cobalt, it is advisable to boil the filtrate till a little of the nickel begins to come down. This precipitate, which will be more or less red

in colour if it contains any cobalt, is filtered off, dissolved, in HCl, and the cobalt estimated as before, and the filtrate which contains nickel is added to the other nickel filtrate. From this solution the nickel may be precipitated by saturating the ammoniacal solution with H_2S filtering off the sulphide of nickel, igniting it, then dissolving in a mixture of HCl and HNO_3, precipitating with caustic potash, and weighing as oxide.

The following experiments were made for the purpose of testing the accuracy of this process, and as there is nothing new in the method of determining the nickel, I confined myself for the most part to the estimation of the cobalt:—

	Cobalt taken.	Nickel taken.	Weight of Pyrophosphate of Cobalt.	Cobalt found.	Nickel found.
I. Exp.	—2·94 grains.	1·8 grain.	7·52 grains.	3·05	—
II. ,,	2·94 ,,	1·8 ,,	7·28 ,,	2·94	—
III. ,,	1·83 ,,	2 ,,	4·96 ,,	1·89	—
IV. ,,	4·20 ,,	4 ,,	10·49 ,,	4·23	—
V. ,,	3·67 ,,	·5 ,,	9·09 ,,	3·67	·53
VI. ,,	4·20 ,,	·2 ,,	10·38 ,,	4·19	·23
VII. ,,	·18 ,,	2 ,,	·45 ,,	·18	—

An experiment in which sulphuric acid was used instead of hydrochloric acid gave the following result:—

Cobalt taken.	Nickel taken.	Weight of Pyrophosphate of Cobalt.	Cobalt found.	Nickel found.
2·94 grains.	2·1 grains.	7·30 grains.	2·95	—

With nitric acid instead of hydrochloric acid the following result was obtained:—

Cobalt taken.	Nickel taken.	Weight of Pyrophosphate of Cobalt.	Cobalt found.	Nickel found.
2·94 grains.	1·00 grains.	7·35 grains.	2·97	—

In addition to the above experiments, I have made a great many estimations of cobalt and nickel in cobalt ore by this process, and I am satisfied that it yields accurate and reliable results not only with large quantities of cobalt in presence of small quantities of nickel, but also with small quantities of cobalt in presence of large quantities of nickel. I may mention that I have had occasion to submit this process to several chemists to be used in the valuation of cobalt ores, and after trial they have admitted that they were satisfied of its accuracy, and preferred it to any process which they had used. I may also add that it has been in constant use in a cobalt work for about a year, and that the chemist of the work,

after comparative trials, has discarded the other processes in its favour.

In estimating cobalt and nickel in ores, I prefer to precipitate these metals as sulphides in an acetic acid solution, and great care requires to be taken to eliminate manganese, as that metal interferes with the correct estimation of the cobalt. The mixed sulphides, after ignition, are weighed for the purpose of ascertaining approximately the quantity of cobalt and nickel then dissolved in nitro-hydrochloric acid, and the cobalt estimated in the manner described.

XVIII.—*Endless Solenoid Galvanometer and Voltmeter.* By Professor James Blyth, M.A., F.R.S.E.

[Read before the Society, 30th April, 1884.]

The instrument consists of a close spiral of insulated copper wire, about two inches in diameter, bent into the form of an anchor ring, so as to constitute an endless solenoid. The coil is placed in a groove of square section turned on the edge of a ring of brass or wood of suitable thickness and diameter, and is fixed therein by passing a fine cord two or three times through its convolutions, then pulling the ends tight and knotting them firmly together. In this way the convolutions of the spiral are close together on the inside of the groove, but a little wider apart on the outside, leaving V-shaped gaps between them. At both ends of the spiral short-lengths of wire are left straight, which, after being well insulated, are twisted together and led to two terminals which serve as electrodes.

The ring containing the endless solenoid is fixed with its plane either vertical or horizontal, as may be found most convenient.

A short magnet is provided, rigidly attached at its centre to the lower end of a fine stiff wire. This magnet is suspended, by means of a silk fibre passed through a fine hole in the upper end of the wire, so as to have its centre in the circular centre-line of the anchor ring formed by the spiral. To the upper end of this wire is attached a long glass fibre or other pointer, which moves over a disc graduated to degrees, or to show amperes directly. When the plane of the containing ring is vertical, the graduated disc is placed horizontally with its plane tangential to the ring: when the ring is horizontal, a graduated sector is attached horizontally to its upper face.

Where weak currents only are to be measured the suspended magnet is allowed to move simply in the field of force due to the earth's magnetism, and we get the following equation for determining the current strength; it being understood that the length

of the magnet is very small compared with the other dimensions of the coil:—

Let n = the number of convolutions of the spiral,
r = the radius of the circular centre line,
H = the horizontal intensity of the earth's magnetism,
C = the current strength,
θ = the angle of deflection,

then $\frac{2\,n\,C}{r}\cos\theta = H\sin\theta$

$$C = \frac{H\,r}{2\,n}\tan\theta$$

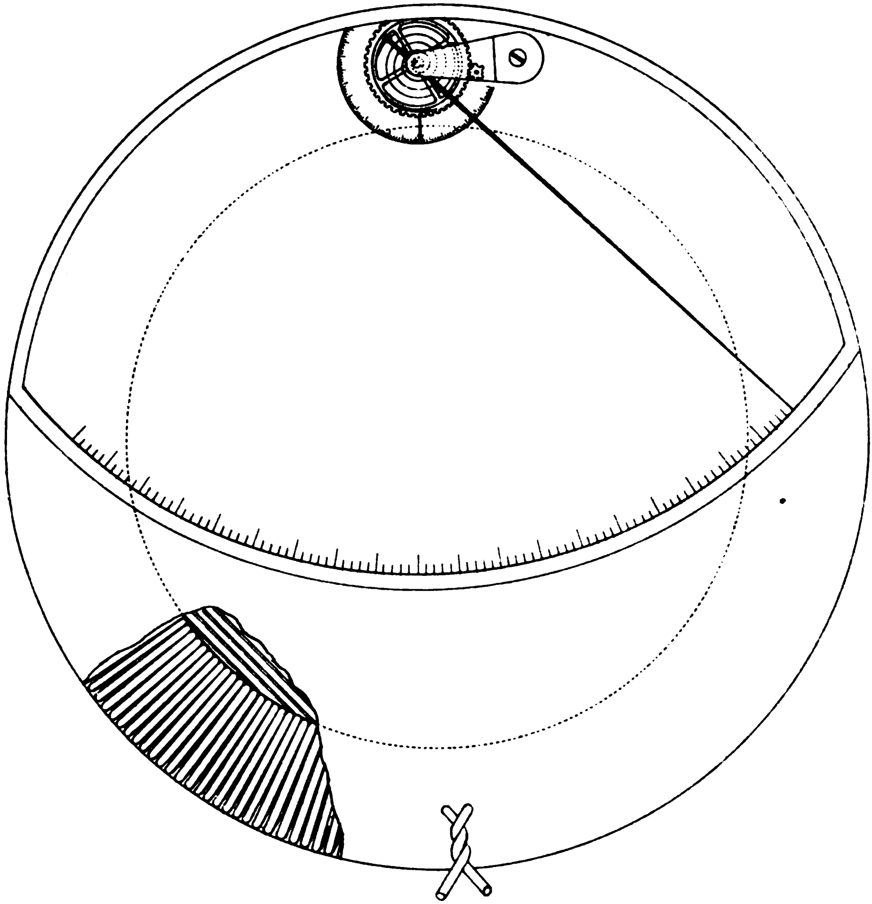
From this it will be seen that the galvanometer constant, $\frac{2\,n}{r}$ admits of easy and accurate determination, seeing that it depends only upon the values of n and r, the one of which is got by simple counting, and the other by careful measurement.

When strong currents are to be measured, the suspended magnet is made to move in a field of force of greater intensity than that due to the earth's magnetism. This is obtained by a permanent magnet of suitable form and dimensions placed so that the suspended magnet hangs in the line joining its two poles. When this is done, in order to get the current strength, we must replace H in the above equation by its value increased by the value of the intensity of the field due to the permanent magnet—a quantity which admits of experimental determination. In practice, however, with a controlling magnet, the constant of the instrument will be most easily determined by passing a known current through it and observing the deflection of the needle.

When the plane of the ring is vertical or horizontal, the controlling magnet is simply an ordinary horse-shoe magnet, placed either vertically or horizontally, so as to clasp the ring with its poles opposite the suspended magnet. This form is shown in Fig. 1, Plate II.

A slightly different form is shown in Fig. 2, Plate II. In this case two short magnets are rigidly attached to the same axis, so as to form an astatic system. The distance between the magnets is so adjusted, that, when the whole is suspended by a silk fibre, the upper magnet has its centre in the centre of the spiral coil, while the lower projects a little below the under surface of the containing ring. The controlling magnet is then fixed so as to have the lower magnet exactly between its poles, and in this way

FIG. 1.



acts solely, or at least mainly, on the lower magnet. A convenient magnet for this purpose consists of a steel bar bent so as to form one convolution of a helix, its ends being kept at the requisite distance apart, as represented in Fig. 3, Plate II.

This form of magnet admits of its being placed in the proper position relatively to the lower magnetised needle, without, at the same time, projecting at any part from below the containing ring.

This form of galvanometer has one distinct advantage over all others in which permanent controlling magnets are used. In them the current, in the act of being measured, creates a magnetic field of its own, which acts upon the magnetism of the controlling magnets. This action, often repeated, tends to produce greater variations in their magnetism than that due merely to their natural want of magnetic rigidity; and hence, in time, must produce serious alteration in the constants of the instruments. With the endless solenoid, however, no such effect can take place, seeing that, when the current circulates in it, it becomes a closed magnetic shell, and, in consequence, can exert no magnetic force at any point outside itself. Hence, when the constant is once carefully determined, the mere use of the instrument tends to produce no change in it, and any change which takes place must be due, either to avoidable accident, or to the natural disturbance which takes place in the magnetism of even the best made permanent magnets.

To avoid altogether the use of a controlling magnet, I have, in one form of the instrument (Fig. 4, Plate II.), replaced its directive action on the needle by that of a spring, which may either be a flat helical spring, like the hair-spring of a watch, or a cylindrical spiral like the balance-spring of a chronometer. In this form, the axis carrying the magnet, or astatic system, is pivoted between agate cups. The spring is placed a little above the upper surface of the containing ring, and has one end attached to the axis carrying the magnetised needle, while the other is attached rigidly to a suitably-placed support. In this way the turning action of the spring on the axis is exactly similar to the action of the hair-spring on the balance-wheel of a watch. A long pointer is attached to the upper end of the axis, and is set so that the angle between it and the magnet is 45°. In this way the pointer can sweep over a sector having an angle of 90°, which allows it to be made of considerable length and the length of the scale divisions proportionally great. In fact, if r = the radius of the

circular centre-line of the spiral coil, the length of the pointer is $r\sqrt{2}$ when the angle through which it turns is 90°.

When a current is sent through the solenoid the needle is deflected, until the couple, due to its electro-magnetic action in the needle, is balanced by that acting on the axis due to the flexural rigidity of the spring. The angle of deflection shows the current strength, and, for greater convenience, the scale is graduated so as to indicate amperes directly. With a delicate spring, weak currents can be measured in this way. To measure strong currents with the same spring an arrangement is provided (Fig. 5, Plate III.) whereby the attachment of the outer end of the spring can be rotated through known angles, as indicated by a separate and shorter pointer. In this way a greater electro-magnetic force is required to produce a given deflection of the needle, and, in consequence, stronger currents can be read. For each position of the short pointer a constant is experimentally determined whereby the indications of the long pointer are made to show the true current. I have also arranged a slight modification of this form, which will sometimes be found more convenient. In it the long pointer is placed parallel to the magnetised needle, and by rotating the outer end of the spiral spring is always brought back to the same position, that position being such that the magnetised needle is perpendicular to the circular centre-line of the spiral coil. The position of the second pointer then shows the current strength. When this is done, the position of the magnetised needle is always such that the couple, acting upon it, due to the electro-magnetic action of the current, is greatest.

In the arrangement with a spiral spring, a magnetically astatic system can be dispensed with by simply tilting the plane of the containing ring to such an angle that the axis carrying the magnetised needle is parallel to the line of the dip. When this is done the needle moves in a plane at right angles to the lines of force due to the earth's magnetism, which, in consequence, has no action upon it.

The voltmeters are constructed precisely on the same plan as the galvanometers, the only difference being that the spiral is made of very fine wire, so as to introduce the requisite great resistance.

FIG. 1.

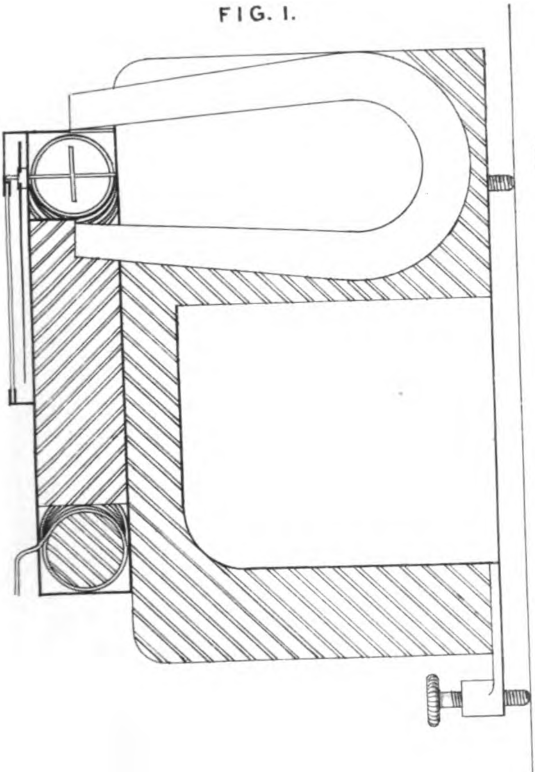


FIG. 2.

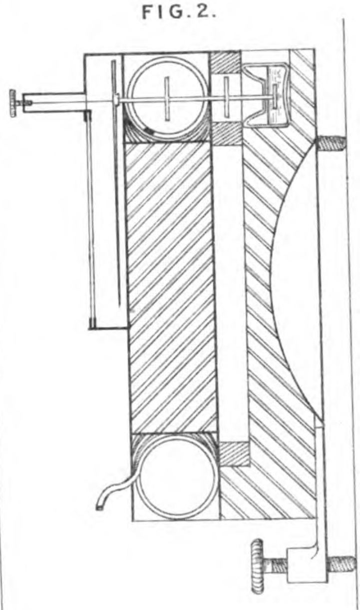


FIG. 3.

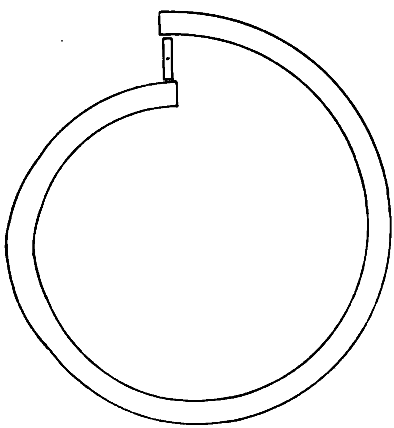
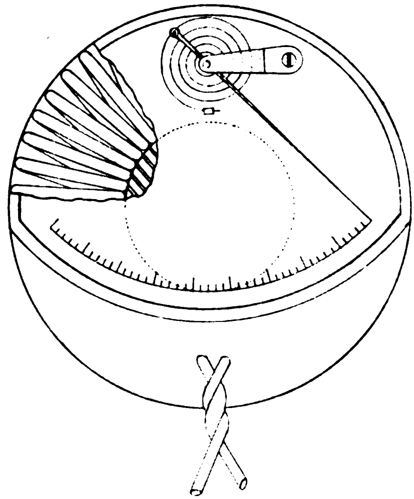


FIG. 4.



XIX.—*Abstract of Paper on the Chemical Constitution of the Methyl and Ethyl Alcohols, as also of their numerous Oxidation Products and Derivatives, viewed and interpreted from the standpoint of the "Typo-Nucleus" Theory.* By OTTO RICHTER, Ph.D.

[Read before the Chemical Section, on 7th January, 1884.]

ACCORDING to the author, the action of oxidising agents upon the methyl and ethyl alcohols gives rise to two typically distinct groups of derivatives, inasmuch as the members of the first group are all constructed upon the type of a univalent basic hydrogen nucleus, H_2; while the members of the second group are all constructed upon the type of a bivalent acid carbon-nucleus, C_4. The annexed scheme is intended to exhibit these theoretically most interesting and important relations.

A. *Formyl System.*—Parent Mol. Methan., $2H_4C_2$: Basic derivatives—the methyl and formyl alcohols, with the respective formulæ H_2C_2; H_2O_2 and C_2; H_2O_2. Acid derivatives—the biformous, biformic, and biformoic acids, with the respective formulæ $2H$; $C_4 - 2(HO_2) \div 2H$; $C_4O_4 - 2(HO_2)$ and $2H$; $C_4O_8 - 2(HO_2)$.

B. *Acetyl System.*—Parent Mol. Ethan., $2H_6C_4$: Basic derivatives—the ethyl, acetyl, and carbyl alchols, with the respective formulæ H_4C_4; $H_2O_2 \div H_2C_4$; H_2O_2 and C_4; H_2O_2. Acid derivatives—the biacetous, biacetic, and biacetoic acids, with the respective formulæ $2H_3C_2$; $C_4 - 2(HO_2) \div 2(H_3C_2)$; $C_4O_4 - 2(HO_2)$ and $2H_3C_2$; $C_4O_8 - 2(HO_2)$.

With reference to the preceding scheme, the author has been led to deduce the general law; namely—that the hydrocarbons, from the simplest to the most complex, are, each and all, capable of entering into direct chemical union with a hydrogen or bicarbon nucleus, and that, in this union, two mol. of the former kind are invariably taken up by one mol. of the latter kind. With this

all-important law to guide him, the author then proceeds to enquire more minutely into the origin and mode of formation of the two alcohols in question. Commencing with the methyl alcohol, he has good reason for believing that it is a product of the direct union of oxygen with hydride of methyl, or so-called methan, which claims, therefore, to be regarded as the true parent mol. of that alcohol. We know also that, with the aid of hydrate of potash, lignin and other amylaceous substances, after becoming converted into grape sugar, are found to yield our alcohol according to the equation, $2[(C_2;\ H_2O_2) \smile 4(C_2;\ H_2O_2)] + 12(KHO_2) = 2(H_2C_2;\ H_2O_2) + 2H;\ C_4O_4 - 2(KO_2) + 2H_3C_2;\ C_4O_4 - 2(KO_2) + 2C_4O_4 - 4(KO_2) + 8H_2$. In this reaction, $4(KHO_2)$ resolve themselves first of all into $2K_2O_2$ and $2H_2O_2$, whereupon the two water mol., by reacting upon two mol. of lignin, transform that compound into four mol. of grape sugar, $(C_2;\ H_2O_2 \smile C_2;\ H_2O_2 \smile C_2;\ H_2O_2)$, which are speedily made to resolve themselves into six mol. of biformyl alcohol $(C_2;\ H_2O_2 \smile C_2;\ H_2O_2)$. Two of these latter mol. are then made to split up into four mol. of water and the modified bicarbon nucleus, $2C_2;\ C_4$, which, by reuniting with these four water mol., gives birth to a mol. of biacetic acid. In the next stage another couplet of these biformyl alcohols breaks up into four water mol. and two bicarbon-nuclei, which, by reuniting with the four water mol., engender two mol. of biformous acid. Again, one of the two remaining biformyl alcohols breaks up into two mol. of water and a bicarbon-nucleus, which, by reuniting with the two water mol., gives rise to a mol. of biformous acid, while the other mol. of biformyl alcohol resolves itself into two mol. of formyl alcohol. Finally, the elements of two water mol. being shared between these two mol. of formyl alcohol and the bicarbon-nucleus, the end products will be two mol. of methyl alcohol and one mol. of biformic acid. It is scarcely necessary to add, that the eight mol. of hydrogen gas derive from the decomposition of eight water mol., whose oxygen serves to convert the two abovementioned biformous acid mol. into two biformoic acid mol.

In passing on to enquire into the origin and mode of formation of the ethyl alcohol, the author has good reason for believing that it is a product of the direct union of oxygen with hydride of ethyl, or so-called ethan, which claims, therefore, to be regarded as the true parent mol. of that alcohol. We know also that it is one of the chief products in the fermentation of grape sugar. In this process two mol. of grape sugar conspire towards the formation

of two mol. of ethyl alcohol and one mol. of biformoic acid, according to the equation, $2(C_2;\ H_2O_2 \smile C_2;\ H_2O_2 \smile C_2;\ H_2O_2) + H_2O_2 = 2(H_4C_4;\ H_2O_2) + 2H;\ C_4O_8 - 2(HO_2)$. The *rationale* of this interesting metamorphosis is believed to be as follows:—The first stage is marked by the formation of a bicarbon-nucleus, for which the material is furnished by those two component formyl alcohols that occupy the third or highest place in the system. Accordingly, the said alcohols resolve themselves into two mol. of water and two mol. of formen, C_2, which become immediately condensed into the bicarbon-nucleus, C_4. In the second stage the two residual biformyl alcohols speedily combine as inner adjuncts with that bicarbon-nucleus so as to yield the compound, $2(C_2;\ H_2O_2 \smile C_2;\ H_2O_2;\ C_4)$. In the third stage the elements of the first water mol. unite as inner and outer conjuncts with the modified bicarbon-nucleus with formation of a mol. of biglycerous anhydride, $2(C_2;\ H_2O_2 \smile C_2;\ H_2O_2);\ 2H;\ C_4O_2$; when the latter, by combining with the second water mol., gives rise to a mol. of biglycerous acid, $2(C_2;\ H_2O_2 \smile C_2;\ H_2O_2),\ 2H;\ C_4 - 2(HO_2)$. In the fourth stage the two colligated biformyl alcohols resolve themselves into two mol. of carbyl alcohol, $C_4;\ H_2O_2$ and two mol. of water, when the resulting product will be expressed by the formula, $2(C_4;\ H_2O_2),\ 2H;\ C_4 - 2(HO_2)$. In the fifth stage, the hydrogen of two water mol., by uniting with the two mol. of carbyl alcohol, gives birth to two mol. of acetyl alcohol, while the oxygen serves to convert the biformous acid into biformic acid. The resulting product will, therefore, be expressed by the formula, $2(H_2C_4;\ H_2O_2),\ 2H;\ C_4O_4 - 2(HO_2)$, which proves it to be identical with ordinary bilatic acid. It deserves special notice that, up to this point, the molecular changes which accompany vinous fermentation are precisely the same as those which accompany lactic fermentation, but, from that point upwards, the two processes differ from each other in this important particular that, in the former case, the elements of two water mol. are yet brought into the field of action, so as to transform the bilactic acid into two mol. of ethyl alcohol and one mol. of biformoic acid, whereas, in the latter case, the bilactic acid suffers no further change and may be secured by the ordinary methods.

XX.—*On the use of Litmus, Rosolic Acid, Methyl Orange, Phenacetolin, and Phenolphthaleïn as Indicators.* Part III. By Robert T. Thomson.

[Read before the Chemical Section, 11th February, 1884.]

The following notes are a further continuation of my former papers on the same subject:—

I.—Determination of small proportions of hydrate in presence of large quantities of the carbonates and other compounds of sodium and potassium.

There are excellent processes for the determination of large proportions of hydrate in solutions which contain comparatively small quantities of the alkali metals, but in the converse case chemists are forced to fall back on methods which are open to serious objection. This state of matters can, however, be remedied by the use of a method which I have employed, and which is principally based on the neutrality of precipitated carbonate of barium to phenolphthaleïn, a fact which I had occasion to make known in the second part of this paper. The process consists in adding to the solution of the carbonate of sodium or potassium excess of chloride of barium solution, which has been previously carefully neutralised, using phenolphthaleïn as indicator. A double decomposition thus occurs, chloride of sodium and carbonate of barium being produced, while the hydrate remains in solution. It is now only necessary to add a little more phenolphthaleïn, and titrate with standard acid, the number of c.c. consumed being calculated to hydrate of potassium or sodium, as the case may be. The whole process must be carried out *in the cold*, for reasons immediately to appear. It is clearly evident that the results will be quite as accurate whatever proportion the hydrate may bear to the carbonate, and the method would thus be useful on many occasions where the use of phenacetolin as indicator would be inadmissible, or at least would give very unsatisfactory determinations. To test the process, two grams. of pure carbonate of sodium,

prepared by igniting bicarbonate of sodium at a temperature just short of the fusion point of the former salt, were dissolved in water, mixed with a quantity of standard caustic soda containing ·02 gram. of pure hydrate of sodium. This mixture would represent a sample of carbonate of soda containing about one per cent. of the hydrate. To the solution, excess of chloride of barium was now added, and for three experiments 4·9, 5, and 5·1 c.c. of decinormal sulphuric acid (1 c.c. = ·004 gram. NaHO) were consumed respectively. The average of these results is exactly ·02 gram. of hydrate of sodium, which was the proportion added.

Similar results were obtained in the determination of hydrate of potassium under the same circumstances as those just described.

In the second part of this paper I showed that precipitated carbonate of calcium was, when boiled, neutral to phenolphthaleïn, and experiments were therefore made in which chloride of calcium was employed to decompose the carbonate of sodium instead of chloride of barium, the titration being necessarily accomplished in a boiling solution, or at least after it had been boiled. It was found that in every case the amount of hydrate of sodium obtained was under the truth, and at the same time the results varied from each other to an appreciable extent. It would seem that some hydrate of calcium is formed, is entangled or combines with the precipitated carbonate of calcium, and thus remains insoluble.

When the sodium carbonate was decomposed by the barium salt, and the titration accomplished in a boiling solution, the results were likewise low, though not to so considerable an extent as when the calcium compound was employed. This, then, is the reason for carrying out the process from beginning to end in a cold solution.

Having now established the accuracy of the process when hydrate and carbonate only are being dealt with, the advisability of taking into account the limitations to which it may be subject must not be overlooked. For this purpose it is necessary to discover the influence, if any, which would be exercised by the impurities often met with in commercial carbonates of sodium and potassium. It is evident that the chlorides of these metals cannot have any effect, as they are not decomposed by the barium chloride, and are neutral. The sulphates and sulphites were tested after being precipitated with the barium chloride, but the full amount of hydrate was obtained. If titrated directly, one-third of the base existing in the tribasic phosphate of sodium or potassium is determined by standard acid; but I found that the phosphate of barium precipi-

tated by the chloride of barium added was neutral to phenolphthaleïn, and that it did not interfere to any appreciable extent with the accuracy of the results. Half of the base existing as sulphide is estimated even after addition of the chloride of barium, but it was found that if a few drops of hydrogen peroxide is added, and the solution allowed to stand for a few minutes, the sulphide is completely converted into sulphate, and thus rendered harmless. The only other compounds likely to be present are the silicate and aluminate of sodium or potassium. In the case of the latter compound, the whole of the soda or potash will be determined; while in the silicate it was found that, although barium silicate was precipitated, about 90 per cent. of the base was obtained, or exactly the proportion brought out by the direct titration of the alkaline silicate. The composition of the sodium silicate adopted is that of ordinary "soluble glass" ($Na_2Si_4O_9$).

The foregoing method can also be applied to the determination of hydrate of sodium or potassium in various other compounds, which give precipitates with barium chloride neutral to phenolphthaleïn, such as the normal sulphites and phosphates of the alkali metals. An illustration of the use to which the facts I have stated in this and former papers may be put will be found in the analysis of sulphite of sodium, samples of which I had occasion to analyse. Of course sulphate, thiosulphate, and chloride are determined as usual, but to estimate sulphite, carbonate and hydrate, or bicarbonate of sodium by methods in ordinary use is rather a tedious operation. To find the proportion of hydrate, all that is necessary is to precipitate with chloride of barium and titrate with standard acid, as above described. Then, by simple titration of another portion of the sample in the cold, using phenolphthaleïn as indicator, the hydrate and half of the carbonate can be found, and finally, by employment of methyl orange as indicator, and further addition of acid, the other half of the carbonate and half of the sulphite of sodium can be estimated. By simple calculations, the respective proportions of these three compounds can be obtained, a result which can be accomplished in a few minutes. It must be borne in mind that if a large quantity of carbonate of sodium is in the sample the proportion of that compound found will only be an approximation to the truth, as the end-reaction is only delicate with small proportions of carbonate of sodium. If there is no hydrate found, bicarbonate of sodium can be tested for, and determined by the method to be described.

II.—Determination of bicarbonate of sodium or potassium in presence of the normal carbonate.

The method I would propose for this rests on the same basis as that which has just been under consideration. In consists in adding to the cold solution of the sample an excess of standard caustic soda, the strength of which has been accurately tested as regards sodium hydrate by the method described above, then adding barium chloride, and estimating the excess of hydrate of sodium employed by standard acid. This result is subtracted from the total caustic soda used, and the remainder, which has been consumed in converting the bicarbonate into normal carbonate of sodium or potassium, calculated to the first-mentioned of these salts. To put this process to the test, two grams. of pure carbonate of sodium were mixed with ·03 gram. of the bicarbonate, and the whole dissolved in cold water. To the mixture 5 c.c. of decinormal hydrate of sodium, then excess of chloride of barium were added, and finally decinormal sulphuric acid, of which 1·4 c.c. were consumed in one experiment and 1·5 in another. This shows that in the first case 3·6, and in the second 3·5 c.c. of the decinormal alkali, were consumed in neutralising the bicarbonate of sodium, the calculated results being equivalent to ·03024 and ·0294 gram. respectively of that salt, instead of ·03 gram. actually used.

Another test was made with two grams. of a sample which contained 88·6 per cent. of bicarbonate of sodium. To the cold solution 25 c.c. of normal sodium hydrate were added, and, after precipitation with barium chloride, exactly 4 c.c. of normal acid were consumed. This represents 1·764 gram. of $NaHCO_3$, instead of 1·772 gram. really present.

As will be seen at a glance, this method is a modification of that described by Lunge (*Jour. Soc. Chem. Industry*, I., 57), the essential difference consisting in the use of phenolphthaleïn as indicator. By this means the time is saved which would otherwise be consumed in removing the carbonate of barium precipitate when the latter process is employed.

III.—The arseniates of sodium and potassium, and determination of arsenic acid in these compounds.

A series of experiments were made with normal arseniate of sodium (Na_3AsO_4), with the view of observing the behaviour of

that salt toward the five indicators before treated of, when titrated with standard sulphuric acid. Arsenic acid was first prepared by oxidizing 9·9 grams. arsenious acid (As_2O_3) with nitric acid, and evaporating over a water bath several times, with addition of water, till all the nitric acid was expelled. The arsenic acid thus obtained was dissolved in water, 300 c.c. of normal caustic soda solution added, and the whole made up to 500 c.c. The caustic soda had been nearly entirely freed from carbonate by adding a slight excess of barium chloride, then removing the excess of barium salt by addition of sulphate of sodium, allowing the precipitate to settle thoroughly, and syphoning off the clear fluid. For each test 50 c.c. of the arseniate solution were employed, and this quantity contained exactly 2·08 grams. of normal arseniate of sodium, which is equivalent to ·93 gram. of soda (Na_2O) and 1·15 gram. of arsenic anhydride (As_2O_5). But, to make sure that no arsenic acid had been lost by spirting or other means during the oxidation and evaporation just described, a determination was made by precipitation as ammonium magnesium arseniate, the weight of which showed that the solution contained the proportion of sodium arseniate (Na_3AsO_4) stated.

Litmus.—When this indicator was employed 19·9 c.c. of normal acid were required to effect the neutralisation. After adding about two-thirds of the acid the blue colour had become purple, and onwards from that stage the blue was gradually discharged, until the pure red only was observable. Owing to this gradual change in colour, it is very difficult to detect the point at which the last trace of blue or purple is eliminated, and, indeed, this can only be done with any degree of accuracy by comparing the solution which is being titrated with an equal volume of water containing the same proportion of litmus reddened by an excess of acid.

Rosolic acid acts in every way like litmus, the change in colour being very slow, and the end-reaction very indistinct. To bring to the neutral point 19·85 c.c. of the normal sulphuric acid were added. This is equal to ·614 gram. of soda, or about two-thirds of that contained in the normal arseniate used, so that the mono-sodium salt (NaH_2AsO_4) may be said to be practically neutral to both rosolic acid and litmus.

Methyl orange.—For two experiments made with methyl orange as indicator, 20 and 20·05 c.c. were respectively consumed, the average of these being equal to ·6207 gram. of soda, or about exactly two-thirds of the soda present. Not the slightest change

in colour was observed until the amount of acid quoted was added, and then only a slight tinge of pink was imparted to the yellow colour, so faint that without some practice it is almost impossible to detect it without comparison with the same bulk of water coloured with a quantity of methyl orange equal to that which has been employed in the titrated solution. A few drops more of the standard acid brought out the full pink colour, so that this intensification of colour can be used in confirmation of the first result.

Phenacetolin acted in much the same manner as litmus and rosolic acid, the end-reaction being very ill-defined. To bring to the neutral point, 19·9 c.c. of normal sulphuric acid were consumed.

Phenolphthaleïn acts in an entirely different way to any of the other four indicators. It differs from litmus, rosolic acid, and phenacetolin in giving a well-defined end-reaction, and is also dissimilar to these and to methyl orange in indicating the neutral point at a different stage of the process. In two experiments in cold solutions exactly 10 c.c. were consumed for each, a result which is equivalent to only one-third of the total soda. It is thus established that, while the mono-sodium arseniate (NaH_2AsO_4) is neutral towards the four indicators just enumerated, the disodium salt (Na_2HAsO_4) is neutral to phenolphthaleïn. When used in a boiling solution, the last-named indicator gives a sensibly higher result.

TABLE I.

RESULTS OBTAINED IN THE TITRATION OF NORMAL SODIUM ARSENIATE.

Na_3AsO_4 used for each test, ... 2·08 grams.
$=Na_2O$ do. do., ... ·93 ,,

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2O found.
Litmus, ...	19·9	·6169
Rosolic Acid, ...	19·85	·6154
Methyl Orange	20 – 20·05	·6200 – ·6215
Phenacetolin, ...	19·9	·6169
Phenolphthalein (cold), ...	10 – 10	·3100 – ·3100
Do. (hot), ...	10·9 – 11	·3379 – ·3410

It is evident that on the definite difference of indication shown

by methyl orange and phenolphthaleïn, a process for the determination of arsenic acid in commercial arseniate of soda may be founded, as I formerly showed could be done for the acids of phosphate and sulphite of sodium. All that is necessary is to dissolve 2 or 3 grams. of the sample in water, filter if necessary, then add standard acid or alkali till the neutral point is reached, with methyl orange. Now boil to expel carbonic acid, cool (if the solution is kept hot, a low result will be obtained), add a little phenolphthaleïn, and determine with normal or half-normal hydrate of sodium. One c.c. of normal soda will be equal to ·115 gram. of As_2O_5. To make sure that carbonate of sodium did not interfere, which it would if all the carbonic acid were not expelled as described, 50 c.c. of the sodium arseniate solution used for testing the indicators were measured off, 1 gram. pure carbonate of sodium added, and the experiment proceeded with. Of the normal caustic soda 10 c.c. were consumed, which is equal to 1·15 gram. of As_2O_5, or exactly the proportion present. The only substance in "arseniate of soda" likely to influence the accuracy of the method is arsenite of sodium or arsenious acid, which, as I will show immediately, would tend to give somewhat high results. I may state, however, that in several samples of commercial arseniate tested by myself I have failed to detect even a trace of arsenite.

Tests were also made with potassium arseniate, but it was found that it acted in every particular in precisely the same manner as the sodium compounds.

IV.—Arsenite of sodium and potassium.

For the purpose of experiment, 9·9 grams. of pure arsenious anhydride (As_2O_3) were dissolved in 100 c.c. of normal caustic soda freed from carbonate, and the whole made up to half a litre with water. For each test 50 c.c. were employed, and this quantity would contain 1·3 gram. of sodium arsenite ($NaAsO_2$), or ·31 gram. of soda (Na_2O).

Litmus.—When this indicator was used 10 c.c. of normal acid were consumed, and, although the blue colour became purple towards the end of the experiment, the end-reaction was easily recognised. The amount of soda obtained was exactly that present.

Rosolic acid behaved in much the same way as litmus, the colour changing slowly towards the end, but the end-reaction being distinct.

Methyl orange.—With this indicator 10 c.c. were consumed in two experiments, which gave exactly the amount of soda present. The end-reaction was quite as delicate as with carbonate of sodium, thus proving that arsenious acid is neutral to methyl orange.

Phenacetolin behaves in every respect like litmus and rosolic acid.

Phenolphthaleïn differs from the other indicators in showing the neutral point after the addition of 9·05 c.c. in one test and 9·1 in another. This was in a cold solution, but when boiled 8·9 and 9 c.c. were respectively required. The colour in this case also changed slowly towards the end.

TABLE II.

RESULTS OBTAINED IN THE TITRATION OF SODIUM ARSENITE.

$NaAsO_2$ used for each test, ... 1·30 gram.
$=Na_2O$ do. do., ... ·31 „

Name of Indicator.	C.C. of Normal Acid consumed.	Gram. of Na_2O obtained.
Litmus, ...	10	·310
Rosolic Acid, ...	10	·310
Methyl Orange, ...	10 – 10	·310 – ·310
Phenacetolin, ...	10	·310
Phenolphthaleïn (cold), ...	9·05 – 9·1	·2805 – ·2821
Do. (hot), ...	8·9 – 9·0	·2759 – ·2790

With arsenite of potassium similar results to those obtained with the sodium salt were brought out.

It will be observed that arsenious acid, although neutral to methyl orange, requires a considerable quantity of soda or potash to render it neutral to phenolphthaleïn, and it is for this reason the presence of an arsenite in arseniate of sodium would give the proportion of arsenic acid above the truth.

In conclusion, I may state that I have made experiments with the view of basing a process for the determination of boric acid in borates, on the difference of indication shown by phenolphthaleïn and methyl orange. These have ended in failure, owing to the extremely indistinct end-reaction with the former indicator, even when small proportions of borate are operated upon.

XXI.—*Sketch of the present state of our knowledge of the Island of New Guinea.* By Walter G. Blackie, Ph.D., F.R.G.S.

[Read before the Society, 16th April, 1884.]

The public interest which has recently been awakened respecting New Guinea, both in this country and Australia, may probably be accepted as a sufficient reason for the attention of this Society being directed for a short time to that large and imperfectly-known island.

It is stated that New Guinea was first seen in the year 1511 by the Portuguese navigators Antonio d'Abreu and Francesco Seram. and that fifteen years later it was visited by another Portuguese, Jorge de Meneses, who named it Islas de Jorge, after himself, although it was then and is still known in the Moluccas by the Malay name of Tanña Papua, the land of the frizzly-haired people. The name Papua is still used by some English writers to designate the island, though most writers agree in restricting its use to designate the inhabitants. Later on in the same century different Spanish navigators, seeking to cross the Pacific from west to east, visited the island, and made known to us in a general way the greater part of the northern coast. One of them, called Inigo Ortiz de Rete, touched at it in 1545, and conferred on it the name of New Guinea, from the resemblance of the inhabitants to the natives of Guinea, on the West Coast of Africa. In the seventeenth century the progress of discovery was continued by various navigators. In 1606, Torres passed along the South and discovered the Strait of his name. In 1643, the year after he discovered Van Diemen's Land (now called Tasmania), Abel Tasman passed along the north-east coast, and was followed in 1700 by Dampier, who discovered the Strait of his name, which separates New Britain from New Guinea. Many other navigators followed in the course of the eighteenth and the early part of the nineteenth century, but the records of their voyages did not add much to our knowledge of this almost *terra incognita.* Indeed, the bulk of the information which we possess respecting

the island, its inhabitants, and products has been derived from explorers who have visited it since 1845, several of whose names will be referred to as we proceed.

A glance at the map of the Pacific Ocean reveals to us the well-known fact that its western boundary is formed by a long line of islands and island groups, which separate it from the Sea of Okhotsk, the Japan Sea, the Yellow Sea, the China Sea, and the Indian Ocean. These islands follow, generally speaking, the line of the coast of Asia, from the most southern point of the peninsula of Kamtschatka to near the Equator, where they turn eastward for about forty degrees of longitude, and then turn south, and ultimately take ending within the Antarctic circle.

In this long series the largest island is New Guinea, and it is also the largest in the world, if we except Australia, which is now generally called a continent. In length it is about 1,530 miles; in breadth it varies from about 30 miles to 410 miles. It contains an area of 303,241 square miles, or, including the immediately adjoining islands, of 311,958 square miles. Consequently it is larger than any country in Europe, except Russia, and its area nearly equals the united area of the British Islands and France (325,690), or of the British Islands, Italy, Turkey, and Greece (324,666). With the islands along its coast, and the groups of New Britain, Admiralty Islands, the Solomon Islands, Queen Charlotte's or Santa Cruz Island, the New Hebrides and Loyalty Islands, all lying to the east and south-east, it forms that division of the islands of the Pacific which geographers have named *Melanesia*, or black islands, from the colour of the inhabitants.

This large island stretches in a direction N.W. to S.E. from about twenty-two minutes south of the Equator through ten degrees of latitude, and is consequently wholly within the tropics. Its most northern and southern points are in 0° 22′ and 10° 42′ S. latitude respectively, and its most western and eastern points in 130° 50′ and 150° 50′ E. longitude respectively. Its outline presents great irregularities, being marked on the north side by the deep recess of Geelvink Bay, discovered in 1705 by the Dutch vessel Geelvink (yellow finch), and on the south-west and south side by the narrow indentation called M'Cluer's Inlet, and the extensive semicircular depression called the Gulf of Papua. Though of considerably inferior dimensions, the indentation of Geelvink Bay corresponds in some respects with the Gulf of Carpentaria, on the north coast of Australia.

As might be expected, the northern and the southern coasts present a considerable contrast, the former, generally speaking, being high and rocky, while the latter is generally low and marshy. The western peninsula of the island, with a mountainous northern border, forms, for a great distance inland, an extensive plain, a characteristic which prevails along the south-west coast as far as M'Cluer's Inlet. On the north coast a strip of low land borders the sea, backed by the Arfak Mountains, which attain an elevation of 7,000 feet above sea level, and by various indications are shown to be of granitic formation. These mountains sink down towards Geelvink Bay. Towards the south they reach the shores of M'Cluer's Inlet, between which and Geelvink Bay they rise to an elavation of 3,000 feet. From M'Cluer's Inlet to Cape Van den Bosch the coast is hilly, thickly wooded, and possesses some small harbours and anchorages, protected by small islands. East of Merkus Ord begins the loftiest range of mountains in New Guinea, containing the highest peaks to be met with between the Himalayas and the Andes. This great mountain chain stretches eastward from Cape Buru along about the fourth parallel of latitude for at least 300 miles. Its western portion was named Charles Louis by D'Urville, and contains peaks 9,000 feet high. Its eastern portion has been named the Snowy range, from its loftiest summits, estimated to attain an elevation of 17,000 or 18,000 feet, being seen from the sea to be covered with perpetual snow. Little is known of this range eastward of long. 139° or 139° 30′ E. It may be, however, and probably is, a somewhat continuous range, which ultimately joins the Albert mountains, and the Owen Stanley range in the eastern peninsula But this is mere conjecture, for all that we really know is, that the Fly River rises in a hill country. Recent discoveries, however, regarding the rivers which flow into the Gulf of Papua, furnish indications that this conjecture may, on the whole, be tolerably near the reality.

The southern coast, from near Cape Buru eastward, round the Gulf of Papua, and on to about lon. 146°6′ is low, generally marshy, beset with mangroves, and very unhealthy. Eastward, along the peninsula formed by the Owen Stanley range, the coast is rocky, pierced by several inlets which form natural harbours, and has various anchorages, protected by the numerous islands which line the coast of this part of New Guinea. Two of these, both surveyed by Captain Moresby, are important enough to receive

special notice. The first is Robert Hall Sound or Harbour, inside of Yule Island, lat. 9° S., lon. 146°3′ E. It is described as being perfectly protected and land-locked, with deep water where hundreds of ships might lie in safety. Two rivers fall into this harbour, one of them navigable for boats for ten miles from its mouth. Yule Island, near which ships would anchor, is high and healthy ground. At other points the land is low and swampy, backed at six or eight miles inland by low hills, behind which range rises after range, till the magnificent Owen Stanley range is reached as a culminating point. The other harbour, called Port Moresby, lies in lat. 9°30′ S., lon. 147°10′ E. It is situated "where coral and white sand has succeeded the low mangrove-covered coast. The entrance is good; and the land, which is covered with many trees, rises gently on either side to a considerable height." An inner harbour of Port Moresby, called Fairfax Harbour, "is an irregular basin, surrounded by round-topped grassy hills, having the Australian gum tree scattered over them, with rich valleys between. The depth of water is between seven and four fathoms to within a few yards of the beach. The sides of the hills are well cultivated, and yield abundance of yams and taro." These harbours will doubless play an important part in the future history of New Guinea.

On the north coast, east from the Arfak mountains, begins Geelvink Bay, measuring about 250 miles W.W.E. and 180 miles N.W.S., and containing many islands. It was not fully explored till 1873, when all its shores were visited by Dr. A. B. Meyer, who also ascended the mountains on its southern shore, 2,000 feet high, and thence saw the sea on the southern coast, near Merkus Ord. Near Point d'Urville, which forms the N.E. extremity of the bay, there is an extensive plain through which the still unexplored river Ambernoli, esteemed by some the largest in the island, flows into the sea. This river, which rises probably in the Snowy mountains, debouches through many arms, forming a great delta, with many low mangrove islands, which are frequently flooded. For 60 or 70 miles eastward the coast retains much of the same character, but the interior is composed of lofty plains, over which rise small isolated hills, which, towards the east, increase in height, and gradually form into a chain. The shore, at first flat, has many small bays which shelter small boats, it then becomes high and rocky, and is beset with a heavy sea whose surf renders landing difficult. At longitude 140°47′ E. we reach

Humboldt Bay, which has an entrance of about five miles wide, flanked by lofty dolomite cliffs. Though its coast is to some extent covered with coral reefs, it presents several good places for anchoring; but the shores do not seem to present a good supply of water. Round the bay the land rises to lofty plains, formed of detritus of red mud and schist, and of a dry and red fertile clay, covered to a great extent with the well-known Indian grass, alangalang (*Imperatus Koenigii*). Captain Moresby, in the *Basilisk*, anchored in this bay, in one of the deep, capacious bights, up which he steered in eight fathoms over a coral reef.

As far as the present state of our knowledge enables us to form an opinion, the northern shore of the S.E. peninsula would seem to be the region best adapted for European constitutions. It was first made properly known to us by Captain Moresby who surveyed it in the *Basilisk* in 1873 from East Cape to Astrolabe Bay. Before doing so, Captain Moresby examined the south-east shore, and surveyed a navigable channel between it and the barrier reef which fringes the coast as far as the western extremity of Torres Strait. He also discovered a navigable channel between the eastern point of the Peninsula and the Louisiade islands, by which vessels sailing from Sydney to Hong Kong effect a saving in distance of 300 miles over the route previously adopted. This channel received the name of the China Strait. Captain Moresby's description of the newly surveyed coast is vivid and interesting. He begins by saying "the first striking differences between these northern and the southern shores of New Guinea are, that here there is no outlying barrier reef, and that the shores, instead of shelving outwards, are steep-to. The mountains here generally run down to the sea; then follows the shore reef, from which the plumb line may be thrown into fifty fathoms water. The coast line is, as a rule, but little broken up, and affords few harbours, but offers several anchorages. Speaking generally, from East Cape to Cape Cretin, a distance of 300 miles, may be spoken of as a series of bold headlands, running out 20 to 40 miles seaward, with steep bays between" (p. 262-3). * * "Between East Cape and Cape Vogel, 100 miles, villages abound, and the valleys, not seen from the sea on account of the lie of the hills, are well cultivated" (p. 263). "Beyond Cape Ducie and Chads Bay the forest ceases and is succeeded by a openly wooded plateau, full of villages, which is backed two miles inwards by a range of sharp

grassy hills, bare of wood, and each defined by a belt of dark brush-wood at its base, and coming crowding down hill upon hill, with such a curious effect as to remind us strongly of the plate in Black's "Atlas" of all the mountains of the world. Above the height of 2,000 feet the forest, singularly enough, springs up again on higher peaks and covers them to the very top at a height of six or seven thousand feet" (p. 265). In Goodenough Bay, beyond Cape Frere, "The villages are scattered along this part of the coast on a plateau of park-like land, which intervenes between the shore and the mountains within, which, rising by gradually higher undulations, terminate at a height of many thousand feet above the sea. There can be no doubt of the capabilities of this land if cultivated; on the hills herds of cattle, and sheep innumerable, might find pasture, whilst from the cold summits to the hot plains all the products of wide extents of climate might be grown" (p. 268). Passing Cape Vogel, which form sthe northern extremity of Goodenough Bay, crossing Collingwood Bay, and rounding Cape Nelson, Captain Moresby was "much impressed by the fine picturesque appearance of Mounts Victory and Trafalgar. These mountains, which are joined by a saddle-shaped ridge, descend to the sea in open grassy and wooded slopes, which have all the appearance of English park land" (p. 271). Rounding Cape Ward Hunt, a large river (which was named the Clyde) was seen discharging itself over a dangerous bar (p. 275). Between Traitor's and Hercules Bays the mouths of several small streams were seen, with alligators basking in them. Beyond Hercules Bay the coast line altered entirely, "the low alluvial land giving place to volcanic hills that came precipitously down to the water's edge, numerous volcanic islands were scattered off the coast, and had a singular appearance, looking as though great morsels had been broken from the hills and thrown into the sea" (p. 281). Beyond Parsee Point in Huon Gulf, a large river was seen, with swampy thickly wooded banks, and a bar at its mouth, to which the name of Markham was given. Beyond this river "the coast trended fifty miles due east, forming the north side of Huon Gulf, and making another of those far projecting promontaries which we have found so characteristic of north-eastern New Guinea. The land is bold, mountainous, and rises to a height of 9,000 feet, it was named by me Rawlinson range, after the President of the Royal Geographical Society. The valleys here and the mountain slopes, dotted with palms and tree ferns, are

especially beautiful and well inhabited; and every valley appeared to be watered by a clear mountain stream" (p. 284).

From Cape Cretin to Cape King William, forty miles, "the coast line presents new features, for along the rear of the beach runs a narrow terrace of good soil, on which a few solitary huts are scattered; and behind this the land rises in rocky plateaux, as regular as the lines of a fortification, divided by ravines, and looming one above the other till they reach the inland Finistere mountains." The altitude of two peaks, which lift their heads boldly above all compeers, was measured, and found to be 11,400 feet (p. 285). They were named Mounts Gladstone and Disraeli. "From Cape King William to Astrolabe Bay, a distance of 100 miles, the coast runs in a W.N.W. direction, and the shores are steep. The mountains are wooded to the beach, and studded with many villages."

Mr. Powell, who visited this coast in 1879, says of the country at Cape King William:—"A more beautiful and healthy spot for settlement than this can scarcely be found in any tropical country in the world; the coast is bold and steep, rising in many places sheer from the sea to the height of about 1,000 feet, and ranging inland to the Finistere mountains, in terraces and table-lands of open grass country, with every facility for cattle grazing, well watered with streams." * * * "The cliffs appear to be of basaltic formation, whilst granite boulders are scattered about the shore. The plains above clearly show that there is a volcano or volcanoes in the vicinity, by the large quantities of rotten pumice-stone scattered about and evergrown with grass. The natives use obsidian for a great number of purposes, such as shaving their heads and faces, carving wood, &c."

Having thus taken a rapid survey of the coasts of this great island, let us turn to the interior, respecting which our knowledge is very limited. What information we do possess centres chiefly round three points—Dorey on the N.W. coast, the Fly River and Baxter River in the Gulf of Papua, and Port Moresby on the southern coast of the eastern peninsula.

Dorey, on the N.W. coast, west of Geelvink Bay, is a small territory, which comprises several villages. It has long been known to traders, and is the head-quarters of some German evangelist missionaries. Its commodious bay presents good anchorage, and its shores and the islands scatered over it are formed of coral. At a short distance inland rise the Arfak mountains, the home of

those magnificent creatures the birds of Paradise. The Arfak mountains follow the line of coast round the western margin of Geelvink Bay, spread over the isthmus which separates that bay from M'Cluer Inlet, and, continuing south, ultimately blend in with the great central range of the island—Charles Louis mountains. In 1858 Alfred Russell Wallace spent three months and a half in Dorey, for a great part of which time he was incapacitated from moving much about by ill health. In the same year it was visited by Count Rosenberg, an official in the Dutch service. The observations of these explorers were confined chiefly to the natural history, and especially the fauna of this region, and very specially to its beautiful birds. Neither of them penetrated beyond the limit of the plain which borders the coast. In 1872, M. D'Albertis, an Italian naturalist, also an ornithologist, arrived at Dorey, and, notwithstanding the bad repute in which the mountaineers were held, he ascended the Arfak mountains, and took up his residence among the natives, at an elevation of 3,500 feet. In his shooting excursions he ascended the mountains to a height of 5,000 feet, and believes them to attain an elevation of 9,000 feet. All these naturalists increased our knowledge of the fauna of the locality, and to some extent of the flora, and give interesting accounts of the inhabitants. Albertis describes the mountains as being thickly wooded, and among the trees he mentions both oaks and araucarias. The climate is rather humid, but (says D'Albertis) it must at the same time be very healthy, because the people who inhabit these mountains are very strong and well built. Notwithstanding the enterprise and daring of M. D'Albertis, more especially in trusting himself alone among an uncivilized people of bad reputation, his explorations did not extend many miles from the shore, so that much more requires to be done before we shall be able to say that we are even reasonably well acquainted with Dorey, Andai, and the country adjoining the western shore of Geelvink Bay.

The Fly River, the largest yet known in New Guinea, falls into the Gulf of Papua about long. 143° 30′ E. It was discovered in 1845 by Captain Blackwood, who named it after his ship, the Fly, and attempted to explore it, but the hostile attitude of the natives caused him to return, after having ascended only a few miles, which did not take him beyond the delta of the river. In 1875, the Rev. Mr. Macfarlane, of the London Missionary Society, in the steamer Ellangowan, and accompanied by M. D'Albertis, ascended the Fly River for 150 miles. The following year M.

D'Albertis made a second voyage to this river in the steamer Neva, and ascended 500 miles, but could get no farther, though his boat was only drawing 3½ to 4 feet of water. In 1877 he made a third voyage up the river, and ascended 475 miles. On all these expeditions the boats were attacked by the natives, who were, however, generally driven off without bloodshed, for when these attacks were made every precaution was taken to escape from them without a hostile collision. On one occasion, however, near the end of his third voyage, M. D'Albertis found it needful, for the safety of himself and associates, to relieve himself of an attack made by a large number of natives by using his rifle. Much of the hostility manifested by the inhabitants on the shores of the Fly River obviously proceeded from their ignorance of the intentions of the explorers, for Mr. Macfarlane, by patience and tact, managed to turn apparent hostility into friendship, and to start a barter trade, which proved useful and pleasant to both of the interested parties.

While the importance of these explorations can hardly be overrated, showing as they do, the existence of a practicable water-way far into the interior of the island, they cannot be said to have made us fully acquainted with the great plain measuring probably 400 miles from west to east, through which the Fly River passes, for none of the travellers ventured far from its banks. The region traversed by this river is covered with "interminable forests which for the best part of the year are under water, and vast grassy plains which are most likely converted into lakes during the rainy season." It falls into the Gulf of Papua by several mouths, which form an extensive delta. The principal known opening forms a channel of ten miles wide. The whole delta indeed has been supposed to be too extensive to belong to the Fly River alone, an opinion which recent accounts seem to confirm. For Mr. Lawes, writing on 19th Dec., 1883, from Port Moresby says, that Mr. Chalmers made an expedition west in the Gulf of Papua, and about long. 145°15′ he found several river mouths, the Alele, Aivei, and Panaroa, which united five miles inland, and were known to the natives as being the mouths of one great river which he named the Wickham. "He is strongly of opinion that the Wickham, the Aird, and the other rivers about Bald Head, are a part of the Fly, or rather that they are all mouths of one large river, of which the delta extends from the Alele to the Fly. Large lakes may be found, of which these large rivers are the outlet."

"The islands at the mouth of the Fly River are very flat and covered with, if not formed of a thick stratum of alluvial land, and are therefore very fertile," but it is very doubtful if Europeans could live upon them.

The Mai-kassa or Baxter river falls into the sea in lat. 9°8′ S., long. 142°18′ E., about 80 miles west from the mouth of the Fly River. It was explored in 1877 by Mr. Octavius Stone, accompanied by the Rev. Mr. Macfarlane in the steamer Ellangowan. It was found to be navigable for an ordinary-sized steamboat for 60 miles, with a width averaging from a mile to a quarter, and a depth from 12 to 3 fathoms. For small boats it is navigable for 30 miles farther, and is there choked up with logs and branches. At the highest point attained there was still 1¼ fathoms water. Mr. Stone imagines that the Mai-kassa may run another hundred miles into the interior. But this supposition is only likely to be sustained should its upper course be found to trend to the west, for the highest point attained being within twelve miles of a reach of the Fly River, a much greater prolongation of its course to the north is hardly probable. The influence of the tide being very perceptible even at the distance of 60 miles from the sea shows the country traversed to be very flat and low. The banks are covered with forest, and the muddy shores are overspread with mangrove. In the rainy season the climate must be very malarious, which is probably the reason that few natives were seen; indeed, the whole voyage was marked by the small amount of animal life observed during it, though some birds were seen each day, and a large boa was killed. This river seems to be frequented by the Dugong, the remains of one having been found on which some of the inhabitants had been feasting.

Leaving the Fly and the Baxter rivers, let us now turn to the region in the neighbourhood of Port Moresby, on the south coast of the eastern peninsula. This fine harbour, discovered by Captain Moresby in 1873, has been made the head-quarters of the missionaries of the London Missionary Society, which has also two other stations, one at Hood's Bay, about 50 or 60 miles south-east from Port Moresby, and another on Murray Island. From Hall Sound or Yule Island to East Cape, the peninsula does not seem at any point to have a breadth of more than 120 miles. At Port Moresby its width is only about one hundred miles, and further east it becomes much narrower. Throughout the whole length indicated it is traversed by the Owen Stanley range of

mountains, some of whose peaks attain an elevation of 13,000 feet, and form admirable landmarks for mariners. Between this range and the south coast there is a lower range of hills, interrupted here and there by breaks or openings of some considerable extent. But as yet no practicable opening through the Owen Stanley range has been discovered; at least no one has as yet crossed the peninsula from sea to sea. With such a conformation of country, large rivers are not to be looked for, as, unless they run parallel to the mountain's chain there is not sufficient distance left between the hills and the shore for a river of any magnitude to be developed. On the other hand, such a conformation in a region of great and pretty constant precipitation would lead to the expectation of many streams being found, though of inferior magnitude. Such has in reality been the case, for the explorations carried on by Captain Moresby, Mr. Stone, Mr. Chalmers, Mr. Lawes, and others, have resulted in the discovery of several streams, most or all of which may be utilised to a greater or less extent as water-ways. Hood's Bay, Port Moresby, and Redscar Bay receive comparatively important streams, which may be ascended in light boats for a distance of 10 to 20 miles. Mr. Stone describes the hills around Port Moresby as being about 400 feet high, becoming higher as they recede from the shore, formed of limestone, and covered with the forest soil, mixed with fragments of decayed coral. These hills, he thinks, must have been upheaved at a comparatively recent period, seeing that at a height of 600 feet he found shells like those existing in the sea at the present day. "These hills are all of a barren nature, partially covered with open forests of gum trees *(Eucalypti)*, averaging 8 or 10 yards apart." "Patches of dark foliage, scrub, and jungle, usually clothe each mountain gully and ravine, at rare intervals the lower portion of the hills being similarly adorned." Here and there fertile valleys and plains are met with. At twenty miles inland a great change takes place in the character of the country, where the home of the Bird of Paradise *(Paradisea raggiana)* is reached. "The gum trees and open country then give way to dense forests of tropical vegetation, tall trees and undergrowths, which completely cover the northern ranges, excepting the upper part of Mount Owen Stanley (13,205) with one impenetrable mass of foliage."

Mr. Lawes, one of the missionaries, writes of this region generally in a similar sense. He says:—"Some voyagers have described these (hills) as fruitful and fertile, and waxed eloquent in praise

of the luxuriant vegetation; while others are indignant at such an account, and speak of them as barren and sterile. All depends on the season of the year in which they are seen. Both descriptions are true. Nothing can be more green and beautiful than the hills after the rainy season, covered as they are with vegetation from their summits to the water's edge. And nothing can be more bare and uninviting than the same scenery after the grass has been burnt in the dry season." * * Again he says:—"The country for miles is covered with coarse kangaroo grass, while the open forest country is studded with white gum, wattles, and other Australian trees. It is only near the water-courses and rivers, or the gorges and ravines of the hills, that the vegetation is luxuriantly tropical. Here are the areca palm, the bread-fruit, wild mango, and chestnut, the pandanus in several varieties, crotons of variegated leaf, crimson dracaenæ, orchids, and creepers in great variety, and ferns in abundance. Near the coast, and especially about Hood Bay, groves of cocoa-nut trees, miles in extent, cast their grateful shade."

Regarding the climate of this region, Mr. Lawes says—"It has hitherto proved very trying, both to Europeans and Polynesians." * * At Port Moresby, in lat. 9° S., the average maximum heat for the whole year was 86·75; and the average minimum or night temperature, 73·5. February was the hottest month, when the average maximum was 90·43, and August the coldest, when the average maximum temperature was 82·3. During six months in the year the wind blows from the south-east, and the other six from the north-west. Towards the time for the change of the monsoon the wind is light and variable; but it can be depended on to blow steadily for four months in each monsoon. The rainy season is from January to May. * * All foreigners have suffered much from malarial fevers. The natives are healthy, although they too suffer slightly from fever."

Turning now to general considerations respecting the island as a whole, it may be remarked that naturalists regard New Guinea, in respect of its fauna and flora, as being a sub-region of Australia —an opinion which derives strong confirmation from the formation of the two islands, apart from resemblances which have been observed between the animals and plants by which they are respectively characterised. Torres Strait, which separates New Guinea from Australia, is only about 80 miles broad at its narrowest point. The average depth of soundings across is 10 to 12 fathoms, and the deepest is 20 fathoms. The Strait is beset

with numerous coral and some volcanic islands, which indicate both subsidence and upheaval. Probably at no very distant date, geologically speaking, the islands were connected by land in place of being as they are now, separated by water—a suggestion that finds support in the fact that the rim or fringe of soundings of 200 fathoms, which surrounds both islands, extends right across from the southern shore of New Guinea to the Gulf of Carpentaria, embracing in its area the Arroo Islands, but excluding the Tenimber Islands, or Timour Laut. Immediately beyond the narrow rim of soundings of 200 fathoms, the depth suddenly increases, first to 1,000 fathoms or thereby, and then to 2,000, and even to 2,600. Generally speaking, this fact applies to both islands all round, except, as we have seen, in the space between them, and, it may be added, the strait which separates Australia from Tasmania. Obviously, therefore, these three islands may be looked upon as parts of one vast plain, measuring about 2,700 miles north to south, and 2,500 miles east to west, with an area of 3,283,785 square miles—approaching that of Europe, which is 3,795,000; and that this great plain, which has elevations on its surface, near its northern extremity, of about 18,000 feet, and near its southern of above 7,000 feet, forms in reality the summit of an enormous mountain, having an elevation, measured from the bed of the ocean, of 15,600 feet, as great as is that of Mont Blanc above the seas. From the bed of the ocean to the top of the snowy range in New Guinea will consequently be above 34,000 feet, or 5,000 feet more than the elevation of the highest mountain in the Himalayas above the sea, and equal to a line perpendicular to the bed of the ocean of above 6 miles in length. Bands of soundings, of a comparatively moderate depth, connect Australia and New Guinea with the New Britain, the Solomon Islands, and even New Zealand, on the one side, and with the Moluccas, the Phillipines, and the Continent of Asia, on the other side, showing their intimate geological relationship, and rendering it probable that at one time they all were directly connected with the great Continent of Asia. The whole of the islands, from New Zealand to the Malay Peninsula, may be conceived of as forming one vast range of mountains, with peaks from 15,000 feet to 34,000 feet high, united as connecting links by lower elevations of 9,000 to 10,000 feet, with here and there profound abysses between, reaching to a depth of 8,000 or 9,000 feet below the level of the general base of the chain of mountains.

Earthquakes are said to be frequently felt in the western portion of New Guinea, but as yet the existence of active volcanoes in the island has not been ascertained. But still, it unquestionably forms a part of that great volcanic belt which passes through the islands forming the western boundary of the Pacific Ocean. In the adjoining island of New Britain there are several active volcanoes, and several others have been observed in the islands which fringe the north-west coast of New Guinea.

Resemblances in some localities to the auriferous districts in Australia led to the supposition that gold might be found in work able quantities. This induced several parties of miners to visit the island in 1878. Some of them prospected the Goldie River for many miles, and returned, after having been out for thirty-two days, reporting that only the colour of gold was attainable. The greatest quantity found in a single dish was one grain, but ten dishes without gold had to be washed for one containing any.

The imperfect state of our knowledge of the island as a whole does not warrant the expectation of much completeness in our information respecting its *fauna* and *flora*. Most of the naturalists who have visited the island having been ornithologists, their attention was, as might be expected, directed chiefly to their own subject. The splendid birds of Paradise formed a special source of attraction. Of these beautiful creatures twenty species are known, most of them frequenting the Arfak mountains, but two are peculiar to the eastern peninsula. Soup made of these birds, Mr. Lawes declares to be "very un-Paradisiacal in its flavour." Like many others of the beautifully-attired feathered tribe, they do not enliven the woods with melodious notes, for their cry is described as like "something between the quacking of a duck and the cawing of a crow." More important, in some aspects at least, than these and other very showy birds are the Megapodius or mound-building fowl, the bush turkey, and, on the river banks, the magnificent-crowned pigeon *(Goura coronata)*, the last as large as a small turkey, with flesh white and delicate in flavour, "the very king of the pigeon tribe." Hornbills of a large size are common in the interior, and the magpie, laughing jackass, and leather-head of the Australians are common everywhere along the south-east coast, and parrots, parroquets, and cockatoos are very numerous." "A species of cassowary is numerous on the plains in the interior. * * The natives hunt them, and they are the fleetest and strongest animals they are acquainted with." Mr. Lawes says, "An old

man, who was praising me most energetically (he hoped I was going to give him a hatchet), having exhausted his stock of flattering adjectives, reached a climax by saying, 'You are like a cassowary.'" Altogether, 400 species of land birds have been described.

The mammalia includes small kangaroos, the opossum, cuscus, flying phalanger, bandicoot, and an echidna, or prickly ant-eater, all marsupials, and closely allied to the North Australian species. The pig is found both wild and domesticated; and dogs, closely allied to the Australian dingo, howl in numbers round every house. They cannot bark, and are not found wild. Among the animals peculiar to the island may be named the *Dendrolagus*, or flying kangaroo, which lives altogether upon trees, and seems to be plentiful in the forest regions, which, in reality, means nearly everywhere.

All the families of the reptiles are represented, and some, such as lizards and serpents, in considerable numbers. On the Fly River, D'Albertis killed a boa fifteen feet in length and of great thickness. Crocodiles are plentiful in the rivers. Insects are numerous, the forms having greater resemblance to those of the Moluccas than of Australia; and many of the butterflies are distinguished by their beauty and peculiarity of form. There are various species of ants, and some of them are very troublesome. A. Russell Wallace says:—"One black kind is very abundant; almost every shrub and tree was infested with it, and its large papery nests were everywhere to be seen. They immediately took possession of my house, building a large nest in the roof, and forming papery tunnels down almost every post. * * * They crawled continually over my hands and face, got into my hair, and roamed at will over my whole body, not producing much inconvenience till they began to bite, which they would do on meeting any obstruction to their passage, and with a sharpness which made one jump again, and rush to undress and turn out the offenders. * * They visited my bed also, so that night brought no relief from their persecution; and I verily believe that during my three and a half months' residence at Dorey I was never a single hour entirely free from them." Bad as these pests evidently are, they seem to be harmless in comparison with the ants met by Captain Moresby when cutting wood for the ship. He says:— "Our greatest annoyance all through was from the ants, with which the New Guinea trees swarmed. They are of various kinds

and habits; some are yellow, and burrow tunnels through the branches; a green species glues large bunches of leaves and twigs together, and forms a nest as large as a beehive; and there are several brown sorts; but one kind attacked us so fiercely that at times we had to leave the victory with them, and choose some other spot for wood. At times, where trees were particularly suitable, and we could not afford to leave them, we had to screw up all our powers of endurance; the officers led the assault, as if it had been a boarding party, and we came off triumphantly with our wood, but bleeding, and with skin full of the forceps of these creatures, which had remained in the wound when we brushed them off."

The vegetation of New Guinea partakes partly of the Indian and partly of the Australian type—the former prevailing on the north-west and the latter on the southern coasts. The island is covered with dense forests of large trees, having exuberant foliage, which come down close to the shore, and even overhang the sea, and in this respect presents a remarkable contrast to Australia. So dense is this forest reported to be that it has been averred that the tree kangaroo might start from the northern shore and skip from branch to branch right across the island, without ever requiring to drop to the ground. Much of the timber is of gigantic size, and comprises cedar, eucalypti, the camphor tree, sago palm, and wild nutmeg. Ferns are very plentiful, and very varied. There are several grasses, more than ten kinds of palms, great quantities of orchids, the tree laurel, a kind of cinnamon (one of the chief articles of commerce), currants, myrtles, several kinds of leguminous plants, and many kinds of the fig tribe, the breadfruit tree, sugar-cane, mango, and two or three kinds of large chestnuts. The natives cultivate rice, taro, yams, tobacco, bananas of various kinds, sugar-cane, cocoanuts, and other tropical productions.

The inhabitants of New Guinea, as we have already seen, are known by the general name of *Papuans*, on account of the frizzly manner in which they dress up their hair—a custom which prevails over the whole island. Though known all by the same general name, they are composed of three distinct races, and a considerable admixture of the three. The Papuan proper, the original inhabitant of the island, is found in the central districts on the north coast, on the south coast, and up the Fly and the Baxter rivers. He is of a negroid type, and is allied to the natives of Australia, and of New Britain, the Solomon Islands,

and other islands of Melanesia, named, as we have already seen, the Black Islands, from the colour of their inhabitants. The other two races are the Malay, in the north-west end of the island, and the Polynesians in the south-east, both of whom have influenced the original Papuans in many ways—the former having unquestionably taught them the art of house-building, and, very probably, the art of constructing the proas with outriggers. Taking the inhabitants of Humboldt Bay as typical examples of the original Papuan, they are blacker, taller, more firmly built, than the other races. Men and women go quite naked; only here and there individuals of the higher classes may be seen with a hollowed out calabash girt in front. The hair is crisp and black, though in many it shows a red colour, caused by it being powdered with a burnt and finely-powdered red clay earth. The brow is high and broad; the eyes, not very large; the nose, big and flat, with, in the case of the men, the septum pierced and ornamented with pieces of wood, coral, or boar's teeth, which imparts to the countenance a peculiarly wild appearance. The women are well formed, of middle size, somewhat lighter in the colour than the men, and, when young, have by no means unpleasant countenances. Tattooing of figures on the breast, back, and arm, is never practised by the men, but is very common among the women, and, indeed, does not look at all ugly (Rosenberg).

The Malay Papuans of the north-west are of a dark brown colour, more or less verging to grey-black; they are smaller of stature than the others, and more fleshy than muscular; relatively very thin legs with well-proportioned bodies are frequently seen. They resemble the negro less than the aboriginal Papuans—the hair is black, thick, very much frizzled, but not woolly; the brow is higher, and the back of the head is more rounded, and the whole build not so powerful as that of the negro. Both sexes go naked except a covering round the loins. The chiefs alone clothe themselves fully, and that only when they receive strangers, when their garments are of white cotton stuff, cut in the fashion of Tidore.

The Polynesian Papuan is found east of Redscar Bay. The men are of a light colour—a warm brown—and neither tall nor stout. They are muscular and well-developed, upright in their gait, and agile in their movements. The nose is fairly well formed, and the lips are neither protruding nor thick. "Many of them have intelligent, pleasing faces, and all the men glory in a huge mop of hair, which stands up all over their heads like a grenadier's cap.

They stick a comb, which is merely a three or four-pronged fork, into this, with a bunch of white cockatoo feathers at the end as an ornament. Many of them are rather fine-looking fellows, and they certainly owe nothing to the tailor's art; no one else can ever wear their clothes." * * "The women wear a decent girdle, or petticoat, which reaches from the hips to the knees, and they are tattooed closely all over. They think it increases the beauty of women, and were surprised (says Mr. Lawes) that my wife was not tattooed, especially as the white skin would show up the pattern so much better than the dark ones." * * * "All their muscles and limbs have free action, they are stately and graceful in their movements, and their use of coloured leaves and flowers no rules of art could improve" (Lawes.)

The Papuans are greatly in advance of their brethren in Australia in respect to their houses, which are all built in the Malay manner, that is, like the crannogs in our own country and the lake-dwellings of Switzerland. The following description by Mr. A. Russell Wallace of a house at Dorey will convey a good idea of the kind of domestic architecture prevailing in New Guinea. "The houses all stand completely in the water, and are reached by long rude bridges. They are very low, with the roof shaped like a huge boat bottom upwards. The posts which support the houses, bridges, and platforms are small crooked sticks placed without any regularity, and looking as if they were tumbling down. The floors are also formed of sticks, equally irregular, and so loose and far apart that I found it almost impossible to walk on them. The walls consist of bits of boards, old boats, rotten mats, attaps, and palm leaves, stuck in anyhow here and there, and having altogether the most wretched dilapidated appearance it is possible to conceive. Under the eaves of many of the houses hang human skulls, the trophies of their battles with the savage Arfaks of the interior, who often come to attack them." This description notwithstanding, the houses are sometimes well built in their way, and at times of very great dimensions. One seen far up the Fly River was ascertained to be 500 feet in length. On the banks of the Baxter River, on the other hand, houses or shelters were met with composed merely of the bark of the gum tree, and fashioned much after the Australian manner, being all open on one side. On the east coast also, near Cape Frere in Collingwool Bay, houses of a different kind were seen. They were not built on piles in the water, nor had they the characteristic saddle roof, but were of an oval form, and

thatched close down to the ground. Differences in construction which clearly point to differences in the race of the constructors.

In the eastern peninsula at all events the stone age still prevails, for the people there have no knowledge of iron. Their war-clubs, brought from the interior, are of stone, the knives and hatchets with which they form their proas are of stone, and they shave the head with a piece of obsidian. Travellers who have seen the natives at work with these stone hatchets hollowing out a boat, aver that they cut quite as well as the *iron axes* do, which are usually to be met with in neighbouring regions. The use of iron, however, is understood in Humboldt Bay, where it has probably been introduced by British or American traders who visit it at times. Still, in war, the stone club is employed. Over the whole island the principal arms seem to be the spear, the bow, the club, and the shield. In some localities the arrows are poisoned. Similarities of this kind prevailing over the island must, we would think, be due to race, that is, to teaching imparted to the original stock, or to direct imitation, for it could hardly arise from the one tribe giving oral information to another seeing that the diversities of tongues are so great that no less than twenty-five languages are said to be spoken in three hundred miles of coast west of Redscar Bay.

The statements made by writers regarding the disposition of the people differ very widely; but, upon the whole, the later accounts present the natives in a light much more favourable than the earlier ones. The disposition they manifest would, indeed, seem greatly to resemble that of many tribes and peoples nearer home—that is, to depend much upon the way in which they are met and the way in which they are treated. Though found at first on the Fly River to be distrustful and hostile, and disposed to attack the boats of the travellers whenever opportunity offered, it was subsequently found possible to trade with them with complete safety, and apparently to the great satisfaction of all parties engaged in the barter which was established. Captain Moresby had one hostile encounter, which was fortunately ended without bloodshed—a rifle bullet which struck the shield of a chief and spun him round so acted upon his nerves that he bolted, and was immediately followed by all his retainers. After that encounter Captain Moresby saw a good deal of the inhabitants, and found them generally docile and kind, so that he and his officers and men mingled with them, without the slightest apprehension of

danger. The most recent accounts indicate that the improvement in the people of the eastern peninsula, arising from the influence of the missionaries, who have been at work there for a number of years, is becoming quite manifest.

Like the Dyak of Borneo, the Papuan is a hunter for heads, with which (or rather the skulls) he decorates his dwelling. Our information respecting the object to be gained by taking heads is far from perfect. Probably we shall not be very wrong in supposing that by this means he seeks to demonstrate his prowess, and thereby, like the Dyak, to render himself worthy of the sable beauty whose hand he demands in marriage. He is vain of the number of murders he has committed, for they entitle him to decorate himself in a peculiar fashion. In the eastern peninsula each murder is indicated by a piece of wood, bone, tuft of hair, or some other object being hung round his neck, and sometimes to the number of twenty; while in the west he decorates his head with the feathers of the white cockatoo, adding an additional feather for each murder he commits. Though the Papuans usually have only one wife, polygamy is permitted, and is, at all events, sometimes practised by the chiefs. Referring to the eastern peninsula, Mr. Lawes says:—"The position of women among the coast tribes is not so low and degraded as is often the case among barbarous races. They are proud and haughty, have very long tongues, and know how to use them; in short, they are able to hold their own, and sometimes a little more." * * "The women can paddle their own canoes quite as well as the men. I have seen a double canoe, propelled by twenty-four women, flying over the water in the lagoon, the women keeping perfect time with their paddles, every arm lifted at the same moment, and every paddle turned simultaneously."

The people in the eastern peninsula seem to have no set religious belief; they fear an evil spirit, but do not seek by sacrifice or offerings to propitiate his favour. In the centre of the island, however, and towards the west end, the people are idolaters, and possess idols of various kinds, and houses or temples in which these idols are kept.

Some writers aver that the Papuan is a cannibal, and others that man-eating is not practised. Having plenty of other food is supposed to be a presumption in his favour, and so it would were cannibalism always resorted to for lack of other food. But this, unfortunately, is not the case, for it is often resorted to on account

of a distinct liking for human flesh. That such is the case with many of the natives of New Guinea has now been accurately ascertained. In the letter of 19th December last, already referred to, respecting the recent journey made by Mr. Chalmers in the Gulf of Papua, a considerable distance west of Redscar Bay, Mr. Lawes says—"He (Mr. Chalmers) found the people generous and hospitable. They are certainly cannibals, but only as concerns their enemies. Sorcery and superstition have their home amongst these tribes. One *dubu*, or sacred house, visited, is described by Mr. Chalmers as the finest he had ever seen. Two large posts, 80 feet high, support the large peaked portico, which is 30 feet wide, while the whole building is 160 feet in length, and tapers down in height from the front. A large number of skulls of men, crocodiles, cassowaries, and pigs, ornament it. The human skulls are those of their victims who have been killed and eaten by them. They speak of this as the greatest luxury, and think those are fools who despise it." Dr. Finsch, a German naturalist, who resided three years in the neighbouring island of New Britain, found the same practice and the same opinion prevailing there. The people, though kindly in disposition, looked upon prisoners of war as booty, and ate them because they liked human flesh. He had the rare opportunity of being present on one occasion when a victim was being cut up. The operators went about the work in the same every-day sort of manner as a butcher in this country does when cutting up a sheep, and the spectators looked as if the matter were an affair of ordinary occurrence.

The people evidently live in settled communities, cultivating various vegetable products, fishing and trading, and are only partially nomadic. In the eastern peninsula the government is patriarchal; the chief having a good deal of power over the family, or small community, but comparatively little over each separate individual composing it. In the west end the chiefs are called rajahs, a name apparently imported by the Malays, and describing probably a state of affairs not differing greatly from that which prevails in the east.

The labours of the German missionaries near Dorey do not seem to have borne much fruit. On the other hand, the labours of the missionaries of the London Missionary Society in the eastern peninsula have been very beneficial. Many of the natives, old and young, are under tuition; and the bearing of the people in the vicinity of the missionary settlements has been obviously improved.

In addition, the missionaries have been very active and very successful in making exploring expeditions to many parts of the coast and the interior; and much of the best information we possess is due to their persistent efforts to open up the country and ascertain the true condition of the people.

Though the flag of Great Britain has been unfurled in several localities of the eastern portion of the island, formal steps have not been taken to annex that region to our Australian possessions. It is somewhat otherwise with the Dutch, who, by acts to be subsequently specified, have annexed the western portion of the island to their government or province of Ternate. In doing so, the Dutch are understood to profess that they merely enter upon the rights of the Sultan of Tidore, a Mahometan prince, who has long been subject to them. It is probable, however, that the rights of this Sultan did not extend on the south coast eastward of Cape Buru, and it is known that on the north coast they were not recognised east of Geelvink Bay; therefore, in making the boundary line extend from long. 140° 47″ E. on the north coast to 141° E. on the south coast, a territory was annexed far beyond the limits covered by the pretensions of the Sultan of Tidore, including, in fact, a region above 400 miles across, and totally unknown.

The first step in this annexation was taken in 1828. On the 24th August of that year the Government Commissary, Van Delden, by proclamation, took possession of the south-west and north coasts, but to what extent does not appear. This act was followed by the building of a wooden fort, named Du Bus, at Merkus Ord, on the south-west coast, lat. 3° 42′ 40″ S., long. 134° 15′ 5″ East; which was abandoned in 1836 on account of the unhealthiness of the locality. The next step was taken in 1848. In the month of July in that year a decree, issued by the Governor of the Dutch East Indies, declared the Dutch territory to extend to a line drawn between Humboldt Bay, long. 140° 47′ E., on the north coast—long. 141° E. on the south coast, and to be included in the Residency of Ternate. As evidence, apparently, of this annexation having been made, four iron-wood posts were erected at various points, each having on it an oval iron plate bearing the Dutch arms, and a legend, *Nederlansch Indie* (Dutch India). These posts, however, instead of being fixed at the extreme limits of the newly-acquired territory so as to mark its extent, were all fixed near anchorages in Geelvink Bay—one at

Dorey, on the north-west coast; another at Sook, on the south coast of the island of Willem-Schouten; a third at the village of Ansus or Ansoos, on the south coast of the island of Jappens or Jobi; and a fourth on the island of Run or Rhun. Besides this the coasts are visited annually by an officer in the war steamer stationed in the Moluccas, for whose use a coaling station has been erected at Dorey. Very soon after this annexation had taken place, the new boundary line was introduced into Dutch maps. We find it carefully laid down in the map of New Guinea, dated 1853, which appears in the elaborate Atlas of the Dutch East Indies, edited from official documents by Baron Melvill van Carnbée. In 1857 the Dutch sent a scientific expedition to survey some portions of the island, and endeavour to find a good position on which to fix a Government settlement. C. B. H. von Rosenberg, a German gentleman in the Dutch service who resided thirty years in the Dutch East Indies, accompanied this expedition, and has given an interesting narrative of his observations in a work entitled "Der Malayische Archipel." Three points were visited, at each of which explorations were made—one on the south-west coast, one on the north-west coast at Dorey, and a third at Humboldt Bay—but the author does not say that a suitable position was discovered. Apparently no action has been taken to establish a Government official on the island, for in 1873 a traveller who wished to obtain protection was informed by the Dutch officials that they could not give it, and that even the German missionaries who were settled near Dorey on the island of Mansinama, were quite independent. It would seem, therefore, that the Dutch authority in the island of New Guinea must be exercised in a very shadowy manner, and far from being such as to warrant the belief that annexation, in the proper meaning of that word, has really taken place.

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XXII.—*How Smoke may be Profitably Consumed.* By ALEXANDER PINKERTON.

[Read before the Society, 30th April, 1884.]

THE "smoke nuisance" is an old and much-discussed subject. As far back as the fifteenth century we learn of active measures having been taken against the nuisance. Since these days the evil has not decreased, and all will agree that, if necessity existed in these times that active measures should be taken with the evil, the need is ten thousand-fold greater now. Authorities have been exercised in every generation, but especially in this, that the offenders should be punishable by criminal procedure, expecting thus to force the employers to look strictly after their stokers. In a few cases, where the power of steam production is ample for their requirements, it is possible, by careful firing, to so decrease the output of smoke that the authorities can make no charge against them. But as these cases were necessarily few, it therefore became needful that a cure should be found for the nuisance; and, as "necessity is the mother of invention," genius was early employed in seeking a remedy. Smoke, it was discovered, is valuable material thrown away, and nothing will call forth ingenuity so quickly as that which affects our purses. But in the interests of health the question has also assumed some importance, so our medical men have expressed themselves strongly on the evils caused by the inhaling of these nauseous gases. It is patent to all that that which blackens the hands and face in a few hours, and soils our linen in a day's time, cannot be acceptable to our lungs. This fact is made almost daily evident to us by numerous living illustrations of sufferers through an impure atmosphere.

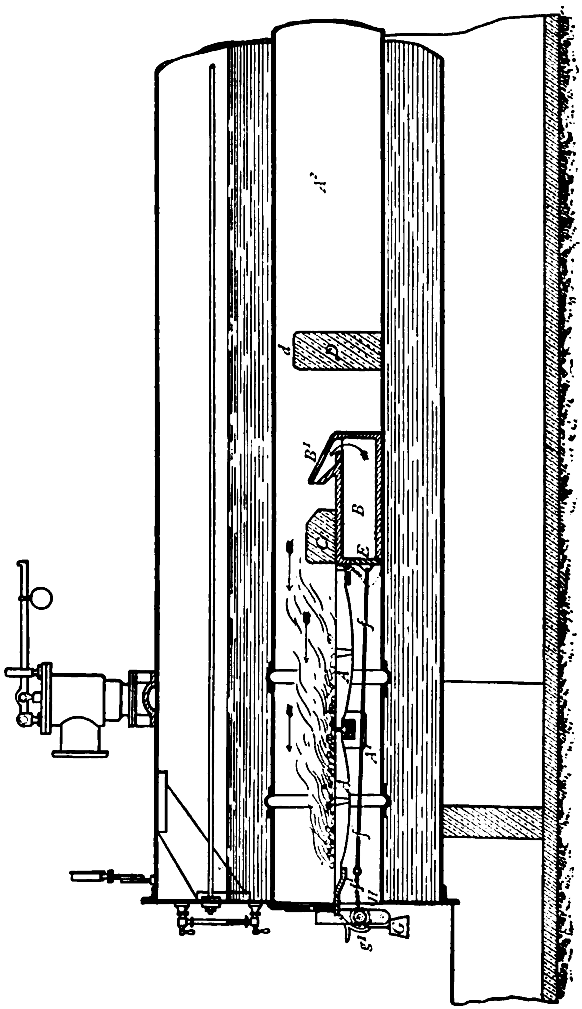
The absence in our great cities of nature's adornment—the green grass and the sweet-scented flowers—is not all attributable to the

value of the soil. On the contrary, we find the deisre for flowers and perfume so strong that all ranks of society attempt their growth in their houses. But the great bugbear to their healthy nourishment is the quantity of carbonic acid which is floating about in the atmosphere, blackening and closing up the lungs of the plant. In the removal of this evil I venture to say that a treble good would be realised. First, we should have a comparatively pure atmosphere; second, we should have a greater abundance of vegetable life to inhale the carbonic acid exhaled from the animal kingdom and from other sources; and third, the pleasure and joy of their presence to all lovers of nature. It were easy to recount a numerous host of evils attendant upon a smoky atmosphere—such as the depreciation in value in all goods exposed for a few days; the increased necessity for renovation of our homes, and the oft-repeated washings of all home napery, &c.; besides the weightier matters already referred to. But this is scarcely needful to prove the necessity of our being at some pains to attain such a desirable end.

Over and over again the subject has engaged the attention of scientific men, and many and most ingenious have been the appliances which have been produced. The passing of air into the furnace in some manner has gained the most acceptance; so we find the doors of the furnaces fitted with special appliances, the fire bridges made hollow or of perforated cast-iron, and also tubes carried over the bridge, with the air outlet immediately beyond. Air forced by steam has also been freely used. The method which I wish to lay before you (as you will have observed from this outline) has simply this old force—atmospheric air applied in a different manner, and to all appearance a more effectual than any yet adopted. Some will say this is a forty-year-old idea, and is threadbare. Such criticism has been passed upon it already; but when the appliances have been seen in operation this judgment has been reversed. If we look into the history of any of the great inventions in use in our time, we shall find that a perfect idea is seldom, if ever, born with the originator of the thought, and as successive minds look into the merits and demerits of the question, improvements are suggested and patented. So with this question. While atmospheric air has a long time been used to aid in complete combustion, the exact method of applying that air is entirely new.

After having experimented for some time, and applying air under different conditions to the furnace, the inventor has rested

with the idea you see illustrated in this outline, and which, so far as he can see, causes perfect combustion, with the *advantages*



A, furnace bars; *A'*, ashpit; *A²*, flue beyond bridge; *B*, cast-iron air box; *B'*, cast-iron nozzle; *C*, spark bridge; *D*, extra bridge behind box forming hot chamber; *d*, circular aperture above bridge; *E*, door of airbox; *f*, rod and chain connecting door of box with ratchet; *G*, drop weight to open door; *g'*, check upon ratchet.

which perfect combustion *should* give. The following may be accepted as a description of the appliance:—

A cast-iron box, say about 30 inches long, and about 2 inches less than the width of the flue, is fitted into the lower half of the flue, immediately behind the furnace bars. The depth of this box

at its centre may be about from 8 to 12 inches, according to the size of the ashpit of the flue. The upper surface of this box, which is flat, reaches to a level with the lower edge of the furnace bars. At the back end of this box we have an aperture 6 inches wide, and extending from side to side of the box; over this aperture a nozzle is fixed, which is inclined towards the furnace. The aperture at the mouth of this nozzle is 1 inch by 30 inches, or more, according to the width of the flue. The front of the box is fitted with a door, hung upon its upper edge, which is opened and closed by an automatic appliance. The first aperture beneath the fire bridge may contain between three and four hundred square inches, the second aperture only contains one hundred and eighty square inches, while the third and last contains only thirty square inches. There is therefore a greater pressure of air put upon the mouth of the nozzle by the gradual contractions which have been made. The ordinary fire bridge is built at the end of the furnace, and rests on the top of the air box in front of the nozzle. A second bridge is built behind the air boxes. The air passage over this bridge is calculated according to the requirement of the flue. It is made circular, higher in the centre, and tapered down at each side to meet the sides of the flue. This bridge has been found to serve several purposes. According to its position at a greater or less distance from the fire, the draft of the flue can be weakened or increased. The fire-brick being heated to a white heat forms an intensely hot chamber in front, and keeps the air box always at red heat. Then the bridge, being circular at the top, spreads the flame round the entire half of the upper part of the flue, thereby giving a greater heating surface. The air box and nozzle, being always at a heat equal to the temperature of the flue, heats the air in its passage through it, so that heated air is supplied to the furnace, and not cold, as some have asserted. One gentleman, dubious of the heat which the box was said to contain, tested it by placing on the top of the box a piece of lead, also hanging the same in the mouth of the nozzle. The lead on the box, when looked for, had been completely melted, and was mingled with the flue dust; that on the mouth of the nozzle had run through into the box, and was also mingled with the flue dust at the bottom, thus proving that the box and nozzle must be red hot.

Respecting the automatic arrangement, the power nearest to the boiler front is made use of, the speed reduced by means of a ratchet, and brought by pinions down to a level with the mouth

of the flue. A rod is passed along the front of the grate, which makes one revolution in six or eight minutes. This rod is turned by means of a small ratchet and a wyper. The fireman, when about to stoke his fire, throws back his furnace door, which action presses a check which allows the weight to drop, causing the rod to make a sudden revolution, and opening the valve on the box by means of the rod and chain connection. The ratch then gradually closes until a blank on the ratch is come to, when it ceases until the furnace door is again thrown back.

The air which supplies the nozzle having to pass beneath the furnace bars is partially heated in its passage. Entering the box, which I have said is red hot, and passing through the nozzle, it meets the gases just above the fire bridge, converting the smoke into a brilliant flame, which fills the furnace, and continues to do so until the smoke is exhausted. Air passed into the furnace by the doors has the tendency to reduce the temperature, or if air were allowed to pass into the flue when the smoke is exhausted the result would be the same; therefore the purpose of the automatic action, which by degrees closes the supply valve and allows less air to pass as the necessity for it decreases, and is entirely closed when the smoke is entirely burned. If air be admitted from the front of the furnace and behind the bridge at the same time, a little light smoke may be seen, but this only lasts the length of time which the furnace door may be open in stoking the fire. If a less supply of air be given than the proportion which I have indicated, total consumption will not be accomplished, and we have found it not disadvantageous to have an abundant supply, for by the regulated action the supply diminishes as the smoke lessens.

Now, it is self-evident that if the smoke be kept in the furnace the flues must have less dust and soot; and such is the case. The flues, which aforetime were wont between cleanings to be half-filled with dust, will now not contain more than three or four inches in the same period. Soot, the natural consequence of smoke, is not now formed. The boiler flues and sides are thus kept in very much better order. They cannot be subject to the same tear and wear as if soot was allowed to gather on the sides and requires a periodical scraping. Being clear of soot, and comparatively clear of dust, a greater heating surface is gained, for there is no better non-conductor than soot. It is possible, therefore, to produce steam much quicker. Smoke is virtually fuel thrown away. To stop this great waste has been the object of

the patentee; but how to do so to profit was the difficulty. By this method, now explained and illustrated, this object has been realised, and the consumer can be guaranteed a saving of the value of the smoke. Passing through the flues a flame instead of black smoke, it stands to reason that greater heat is realised. One test with best Wishaw dross showed that, using this apparatus, 9½ lbs. of water were evaporated to the 1 lb. of coal, and without it 6¼ lbs. of water to the 1 lb. of coal, showing an increased evaporation by 50 per cent. Burning an inferior fuel, less results may be expected. If more steam is not required, then the problem will work both ways, and fuel may be and is saved. The proportion here also varies, according to the quality of material burned. One gentleman tells us that he has a considerable saving of fuel, besides steam to dry 1,000 lbs. of yarn extra per day; this off two double-flued Cornish boilers. Another gentleman accepted the appliance on approbation, with the condition that unless it burned smoke and saved fuel it should be withdrawn. This gentleman has since had other two of his boilers fitted with them. In another case the cost of the apparatus was saved in one year. These are facts worthy the attention of business men, for, while we all like to be credited with philanthropy, it is much easier becoming a public benefactor when we have nothing to lose but everything to gain.

Unless a distinct saving is realised by the consumer, the apparatus is not reckoned successful. In fact, a saving is guaranteed by the patentee.

XXIII.—*Abstract of a communication "On the Prevalence of Rickets in the City of Glasgow and in the West of Scotland, and the Relation of Rickets to the Food and Water used."* By JAMES THOMSON, F.G.S., Honorary Member of the Royal Ducal Society of Jena; Corresponding Member of the Royal Society of Science of Liège; and President of the Biological Section of the Philosophical Society of Glasgow.

[Read before the Society, 2nd April, 1884.]

STRUCK with the prevalence of physical deformities in the limbs of children, the author has for several years been collecting statistical information, and he has also inquired into the causes of such deformities. The results of his inquiry are as follows:—

I.—SUPPOSED CAUSES.

There is a potent reason for my present communication apart from its scientific bearings. There is a humanitarian consideration of no mean magnitude, which must present itself to every well-wisher of the rising generation, *i.e.*, the enormous increase of this dire calamity of late years, namely, rickets in young children. And there is no problem so significant, or so important, as the fact that the increase of these deformities is of recent date; and if there be any fact, or any inquiry which is even more significant or more impressive, it is that as regards the cause or causes of this recent change in the physical aspect of the young and rising generation. As regards the cause of this new condition—so recent, so fresh, all but unknown in preceding times, so clear and close at hand—we have not as yet one single reliable reason assigned for such conditions. The ever active mind of man was never more alive or better adapted to such inquiries; but the kind of explanation needed lies in a higher and a deeper system of

inquiry than has yet existed. We can assign no reason, but we see the products. The facts are these—that the physical aspects of children were more normal not at a remote period, but within the experience even of the youngest members of our Society.

1. *Water Supply.*—Some believe that these deformities are traceable to our water supply. All know that a few years ago there was introduced a new system of water supply, *i.e.*, from Loch Katrine. We also know that its action upon lead is of a most startling character. It is well known that lime salts, one of the essential elements in the formation of bone, are all but absent from Loch Katrine water. We also know that the chemical action of the water upon lead can be arrested by the introduction of a given proportion of lime. A number of years ago I tried a series of experiments with lime, and the results were pronounced in their character. In order to show you that action, and how it can be arrested, I have renewed these experiments. The method pursued is simple and crude, but it will serve our present purpose. I have in each of these five glass jars, four ounces of water, into which I have introduced one ounce of lead. Into No. 1 series I have introduced into four of these vessels common carboniferous limestone, in different proportions; into No. 2 there is added a quarter of an ounce of limestone; into No. 3, half an ounce; into No. 4, three-quarters of an ounce; and into No. 5, an ounce of limestone. In the vessel No. 1, in which there is no limestone, the water became somewhat turbid in twelve hours; the experiment has gone on for sixteen weeks and it is of a milky-white colour. In the other four vessels, in protion to the increased quantity of limestone, the turbidity diminishes.

In order, however, to test this still further, I have introduced into each of No. 2 series of vessels a similar quantity of water and lead, but instead of limestone I have added a solution of slaked lime. In the one in which there is no solution of lime there was a perceptible alteration in the colour of the water at the end of twelve hours. In the others there was introduced the solution of lime, in the following proportions:—10, 15, 20, and 25 minims. The results are equally pronounced, although somewhat different. Instead of the turbid residue we have a number of white flakes, and these decrease in number in proportion to the quantity of lime solution introduced.

In order that this should be still further tested, I introduced into another series of vessels a similar quantity of distilled water.

In one of these there is simply water and lead, similar to what was used in the previous four experiments; into the others, a similar quantity of water and lead, adding 5, 10, 15, and 25 minims of the solution of lime into the different vessels. The results are somewhat similar to that of the preceding, but, if anything, the action of the distilled water is more intense upon the lead than it is in the water that is daily supplied to the community. Such results are suggestive, and provoke the question—If the water in daily use has the elements within it of such a character as to dissolve lead in so short a time, is it possible that it can influence either in retarding the growth, or softening or dissolving the bones of the human body? I am not in a position to answer either in the negative or positive, my object being simply to suggest inquiry.

Simple and imperfect as these experiments are, we have in the results the clearest evidence that the chemical action of Loch Katrine water upon lead can be arrested by the introduction of a given proportion of lime; then, if my crude experiments have not scientific accuracy, they do at least point to a remedy.

2. *Food Supply.*—There is another reason we frequently hear assigned as the cause of these abnormal conditions in the bones of children, *i.e.*, the great change in the character of the food supplied in early life. About eight years before the introduction of Loch Katrine water there was a large reduction upon the duty on tea. Since then the consumpt of tea has largely increased. Now, all know that tea, although a highly conservative article of diet and a refreshing beverage, more especially to the aged, has, however, little nutritious matter in it; it is represented to contain only about 2½ per cent. of albumen, with other constituents it contains fully 15 per cent. of tannic acid. Now, previous to the reduction of the duty upon tea, the food of the labouring portion of the community was more or less varied. In these circumstances oatmeal was largely used—indeed, it might be said to form the staple constituent of the food of the labouring classes. Now I find that since the year 1846 there has been a gradual diminution in the consumpt of oatmeal. It was in that year that the potato blight took place. The inferior quality, the high price, and popular belief that the use of the potato was injurious, necessarily produced a great change in the dietary habits of the people. Up to that period, 1846, oatmeal was the staple article of diet for breakfast

and supper, potatoes were principally used at dinner. For a number of years subsequent to the potato blight the increase in price, the dread of using potatoes, and the great reduction that took place after the prohibitive duties were reduced on the importation of grain, necessarily caused the population to seek a substitute for potatoes—which substitute was found in wheaten bread. The long-continued potato blight, and the compulsory use of wheaten flour produced a corresponding change in the dietary habits of the population, inducing a largely increased appreciation of wheaten bread. And it is to be lamented that a want of chemical knowledge in both the miller and the baker, and the haste to be rich, have fostered, and now pander to, the popular and delusive desire to have white bread. To produce such they are obliged to divest the grain of a portion of its nutritive matter, and thus the food is robbed of a portion of those elements from which the different organs of the body are formed—thus rashly and ignorantly divesting the food of those ingredients which in the chemical laboratory of Nature are dissolved, dispersed, and go to form the bones; they thus only leave in the flour those elements which imperfectly form the flesh and tissues of the body. This degraded taste has been slowly developed; and in proportion to the increased consumption of this masked deception in the form of flour, there has been a diminution in the use of oatmeal—indeed, so much so, that it is no unusual occurrence to hear of working-men's homes in which the old and nutritious article of diet, porridge, is never used—

"The halesome parritch, wale o' Scotia's food."

Thus, in a large proportion of the homes of the community, ignorance of the ordinary principles of dietetics is rudely trampling under foot the essential conditions of a vigorous and healthy existence.

3. *Increased consumption of Sugar.*—There is, however, another article of diet the consumpt of which has largely increased of late years, namely, sugar. A few years ago the duty upon sugar was largely reduced; about that time a number of articles appeared in the newspapers advocating the delusive notion that sugar was a highly nutritive body. The use of sugar has increased to such an extent that, in the densely-populated districts, there is used a much larger proportion of sugar than there is of oatmeal—indeed, in many of the centres of industry the proportion ranges from two to

ten tons of sugar for every ton of oatmeal. Now, in the food we use there are ingredients which, when brought into contact with the digestive juices in the alimentary canal, are converted into sugar before its dispersion throughout the body. The equivalents of sugar and other ingredients are arranged in definite and proper proportions; therefore, if there is any excess of sugar in the alimentary canal, its undue admixture must have a more or less injurious effect, and I venture to state that the conversion of the excess of sugar into acid must interfere with the formation of the calcareous portion of the bones.

The lowering of the price of sugar has induced a large increase in its consumption in varied forms, not only in the ordinary household uses, but it has also fostered a largely increased consumpt of confects and jellies—indeed, the use of the latter has increased in some localities to such an extent that their use is superseding the use of butter, and there is, weight for weight, more jelly used than there is of oatmeal. And it is well known that unprincipled manufacturers of confects and jellies do not use pure sugar in the manufacture. The unnatural and unhealthy competition of the present day has induced some, not only to introduce deleterious mixtures for colouring, but also largely to use glucose, or fruit sugar, for cheapening both confects and jellies.

Now, it needs no elaborate remarks to show that if those articles are used otherwise than as nature prescribes—and more especially by the children—the beautifully equipoised balance of nature is distorted, and fails in supplying those products that go to build up the bones, and, therefore, when the pressure and strain of the superimposed body is put upon the lower extremities, it is but natural to expect that some portion of the limbs will yield and become more or less distorted.

4. *Experiments as to Effects of Strong Solutions of Sugar on Dead Bones.*—In order to know if sugar has an influence, or immediate action on bone, I have in those eight glass jars water, sugar, and the bones of the ox, sheep, pig, and human being, in the following proportions:—Into four of the jars we have four ounces of water, a quarter of an ounce of sugar, adding a quarter of an ounce of bone into each. Into the other four jars, four ounces of water, a half an ounce of sugar, and a quarter an ounce of bone. The bones have been immersed in the water and sugar since 17th of December, 1883. I find that each of the bones is more or less affected. The fatty matter is not

only withdrawn, but there is also a deposition of earthy matter at the bottom of each jar. The amount of these extracted matters is largely increased in the jars in which the larger proportion of sugar is added to the water. We have thus indicated, in these crude experiments, that bones, more or less matured, can be affected by sugar.* With such evidence, it is but a fair inference to suppose that the great increase in the use of sugar must be more or less injurious to the growth of the bones in children.

II. STATISTICAL INQUIRY.

In order that an approximate estimate may be made of the extent and character of the deformities that have of late become so common amongst the children, I have prepared a few statistics from personal observation in different localities.

The method of my observations is not by any means exhaustive; it, however, was the only means my limited opportunities would admit of, and will, I venture to hope, enable us to approximately estimate the alarming extent of the evil; and if we can evoke remedial suggestions, my crude communication, in the absence of scientific data may be of use; and if it lead to more extended inquiry, and more accurate observation, my object in bringing this subject before you will be accomplished.

The method adopted was to visit the localities afterwards to be enumerated during the earlier part of the day, when the young children were out enjoying themselves, and for the older children, either when they were collecting to attend school, or in the afterpart of the day, when they are free from school. In all cases I usually counted all the children that were to be seen in each locality, and noted the deformed, and, as far as possible, the nature of the deformities. For the younger children, I confined my observations to the ages of between 3 to 7 years, and, for the older, from the ages of 7 to 14 years.

From what has been stated, you will readily understand the nature of my inquiry. In order that I may be understood, I will tabulate a portion of my observations, taking them in the order

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* Since this communication was read, James Mactear, Esq., F.C.S., St. Rollox Chemical Works, has kindly analyzed the solution in which the human bone was immersed, and has found that not only the carbonate of lime, but also the phosphates are held in solution in considerable quantities. We thus have the clearest evidence that a solution of sugar, by becoming acid, will dissolve the constituents of the bones.

they were collected; and when noticing the nature and extent of these deformities, I will, as far as my information will admit, give a rough estimate of the proportions of oatmeal and sugar used in the different localities. You must not suppose, however, that these statistics are exhaustive, my opportunities would not admit of such. Let me here notice that, when I first began to observe these deformities, I did not note the nature and extent, as was subsequently done; I simply noted the proportion of the deformed to those presenting no abnormal conditions.

15th July, 1881.

In Abbotsford Place, below Cumberland Street, S.S., the proportion of deformed limbs was 1 in 14 children.

In upper Abbotsford Place, or above Cumberland Street, the proportion of deformities was 1 in 9.

In Mackinlay Street, a continuation of the latter, the proportion of deformed children was 4 in 15, or 1 in $3\frac{3}{4}$. In this street the houses consist of two apartments. In upper Abbotsford Place the houses consist of two, three, and a few with four apartments. In lower Abbotsford Place the houses consist of four, five, and six apartments.

In Bedford Street, S.S., there was 1 child deformed in 7. The houses are varied, and consist of two, three, and four apartments.

In Main Street, S.S., the proportion of deformities was 1 in 6.

In Govan Street, S.S., the proportion of deformities was 1 in 6. The houses in those streets consist of one, two, and three apartments.

27th August, 1881.

In Nithsdale Road, S.S., the proportion of deformities was 1 in 9 children. The houses consist of two, three, and four apartments.

In Main Street, Bridgeton, the proportion was 1 in 4 children, from 3 to 7 years; and 1 in 92, from 7 to 14 years. The houses are mostly one and two apartments.

In Greenhead Street, Bridgeton, there was 1 child in 9 deformed. The houses consist of three, four, and five apartments.

In John Street, Bridgeton, which extends from Main Street to Greenhead Street, there was 1 child deformed in every 3, from 3 to 7 years. The houses are small, and consist of one and two apartments; population largely employed in mills.

In Thistle Street, S.S., near the foot of the street, there was 1 child deformed in 5; ages, from 3 to 7 years.

28th August, 1881.

In the village of Carfin, Lanarkshire, which consists of one street, there was 1 deformed in every 3½ children. The population is mostly Irish; and all employed in coal mines. There is little oatmeal used in this locality.

30th August, 1881.

In Dalry, Ayrshire, there was 1 deformed in 150 children. Oatmeal is much used as porridge, and it is also largely used baked into bread.

26th September, 1881.

In Henrietta Street, Pollokshaws, there was 1 child deformed in 9. There are 8 tons of sugar used for 1 ton of oatmeal, and there is more jelly sold than oatmeal in this locality.

12th March, 1883.

Neilston, 11.20 a.m. Between the ages of 3 and 7 years there was 1 child in 15 deformed. These consisted of knock-knees and bow-legs, and in all instances they are but slightly deformed. Nearly all the cases were amongst incomers to the village. Between the ages of 7 and 14 years there was 1 deformed in 128.

In the village of Neilston there are fewer children seen upon the streets than in any other town in the central valley of Scotland, which can only be accounted for from the fact that females form the greater portion of the population, and these are mostly employed in the thread and other public works, and many of them are thus employed till they are considerably advanced in life. Tea and sugar are largely used. One merchant informs me that he sells twenty tons of sugar for one ton of oatmeal. This is accounted for from the fact that in the public works the hours of labour are from six in the morning to six in the evening, and the distance between their homes and the works is so great that they have not time to cook any other kind of food than tea. Hence the reason for the small number of deformed children and the extraordinary use of tea and sugar.

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2 of the children the legs were much curved laterally outwards, or bowlie; 1, the left leg was much curved laterally outwards, and the right leg was slightly curved laterally inwards; 1, the legs were curved laterally outwards and slightly anteriorly; 1 in which the legs were much curved anteriorly, and the lower portion of the tibia and fibula were much enlarged and overlapped the astragalus and os calcis. 1 child deformed in every $2\frac{3}{4}$.

Caledonian Road, S.S., opposite the gate of the Southern Necropolis, 6 p.m. Ages of children, from 3 to 7 years.

There were 9 children upon the street; 5 of these children were deformed.

1 of the children was badly knock-kneed; 1, the centres of the legs were curved anteriorly at an angle of about 25 degrees; this child could not walk, the head was unusually large; 2, the legs were curved laterally and outwards, or bowlie; 1, the right leg was much curved laterally and outwards about 3 inches below the knee. 5 children in 9 deformed.

7th June, 1883.

Fauldhouse Street, Rutherglen Road, 3 p.m. Ages of children, 3 to 7 years.

There were 9 children upon the street; 4 of these children were deformed in the legs.

1 of the children the legs were much curved laterally inwards in the centre, feet large posteriorly, and flat; 1, the legs were curved anteriorly about the middle; 2, the legs were curved laterally and outwards, or bowlie. There is 1 child deformed in the legs in $2\frac{1}{4}$.

Oatland Square, S.S., 4 p.m. Ages of children, from 3 to 7 years.

There were 17 children upon the street; 5 of these children were deformed in the legs.

1 of the children the legs were laterally curved outwards, or bowlie; 2, the legs were nill-kneed, large feet, abdomen large, and the anterior portion of the head is large; 2 with legs curved anteriorly, one of these was much deformed. There is 1 child deformed in the legs in about $3\frac{1}{4}$.

Braehead Street, off Rutherglen Road, near east end, 4.15 p.m. Age of children, from 3 to 7 years.

There were 8 children upon the street; 4 of these children were deformed in the legs.

1 of these children the legs were curved laterally outwards, or bowlie; 1, the legs were slightly curved laterally outwards; 1, the legs were curved laterally inwards a little above the middle of the leg; 1, the legs were curved anteriorly in the middle of the leg. There is 1 child deformed in the legs in 2.

There are 6 tons of sugar sold in this locality for 1 ton of oatmeal.

Rutherglen Road, Polmadie, 4.40 p.m. Ages of children, from 3 to 7 years.

There were 14 children upon the street; there were 5 of these deformed in the legs.

1 of these children the legs were much curved laterally outwards, or bowlie; 1, the legs were slightly curved laterally outwards; 1, the legs were curved laterally inwards near the upper end of the fibula; 1, the legs were curved anteriorly in the centre: 1, the legs were slightly nill-kneed. There is one child deformed in the legs in $2\frac{4}{5}$.

Oatmeal is bought in single pounds; there are 6 tons of sugar for every ton of oatmeal sold in this locality.

11th June, 1883.

New City Road, 10.30 a.m. Age of children, from 3 to 7 years.

There were 14 children upon the street; there were five of these deformed in the legs.

1 of these children the legs were much curved anteriorly; 1, the legs were slightly curved anteriorly; 1, the legs were curved laterally inwards below the knee; 1, the legs were much curved laterally inwards or badly bowlie; 1, the legs were slightly curved laterally outwards. There is 1 child deformed in the legs in $2\frac{4}{5}$ children.

Oatmeal is little used.

13th June, 1883.

Orchard Street, Partick, 3 p.m.

There were 10 children upon the street; 3 of these were deformed in the legs.

1 of these children the legs were nill-kneed, abdomen and feet large; 1, the legs were curved anteriorly at the middle; 1, the legs

are much curved laterally, or badly bowlie. There is one child deformed in the legs in $3\frac{1}{3}$ children.

13th June, 1883.

Hosier Street, Partick, 3 p.m. Age of children, from 3 to 7 years.

There were 5 children upon the street; there was 1 child curved laterally outwards or bow-legged.

Oatmeal is little used.

14th June, 1883.

Langlands Road, Govan, 4.30 p.m. Age of children, from 3 to 7 years.

There were 11 children upon the street; 3 of these were deformed in the legs.

1 of these children the legs are curved laterally outwards in the middle of the fibula; 1, the leg is curved anteriorly above the astragalus; 1, the legs are nill-kneed, and fibula curved inwards near the middle. 1 child deformed in the legs in $3\frac{3}{4}$.

Oatmeal is bought in single pounds, and little used; there are about 5 tons of sugar sold for 1 ton of oatmeal.

16th June, 1883.

Henrietta Street, Pollokshaws, 12 noon. Ages of children, from 3 to 7 years.

There were 18 children upon the street; 5 of these were slightly deformed in the legs.

2 of these were slightly nill-kneed; 2, the legs were laterally curved outwards; 1, the legs were curved anteriorly. There is 1 child deformed in the legs in $3\frac{5}{8}$.

There are about 3 tons of sugar for each ton of oatmeal sold in this locality. Wheat flour has taken the place of the oatmeal.

20th June, 1883.

Abercrombie Street, Calton, Glasgow, 12 p.m. Ages of the children, from 3 to 7 years.

There were 6 children upon the street. 2 of these were deformed in the legs.

1 of the children was nill-kneed; 1, the middle of the leg was twisted outwards and anteriorly; this child walked upon the outside of the feet. There is 1 child deformed in the legs in 3.

21st June, 1883.

Castle Street, opposite the Royal Infirmary, 11.30 a.m. Age of the children, from 3 to 7 years.

There were 5 children upon the street. 2 of these were deformed in the legs.

1 of the children the legs were curved posteriorly at the knees, the pelvic region was much projected, and the child had great difficulty in walking; 1, the legs were curved anteriorly at the middle. There is 1 child deformed in the legs in $2\frac{1}{2}$.

Albert Street, off Glebe Street, Townhead, 1.30 p.m. Age of children, from 3 to 7 years.

There were 26 children upon the street. 8 of these were deformed in the legs.

1 of these children the legs were much curved laterally inwards below the knee; 1 was nill-kneed; 1, the legs were much curved laterally outwards, or bowlie; 1, the legs were curved anteriorly about the middle; 4 were more or less slightly deformed. There is 1 child deformed in the legs in $4\frac{1}{2}$. These children seemed to be well cared for.

7th July, 1883.

Foot of Carmichael Street, Govan, 2.30 p.m. Age of children, from 3 to 7 years.

There were 10 children upon the street. 3 of these were deformed in the legs.

1 of these children the legs were badly curved laterally outwards, or bowlie; 1 was nill-kneed; 1, the leg was much curved anteriorly in left leg.

There is 1 child deformed in the legs in $3\frac{1}{3}$.

There was 120 children upon the street. Age, from 7 to 14 years. 2 of these were deformed in legs.

1 of these, a girl, was badly curved laterally outwards; 1 was slightly curved laterally outwards.

There are 4 tons of sugar sold for 1 ton of oatmeal.

20th July, 1883.

Victoria Street, Govan, 11.30 a.m. Age of children, from 3 to 7 years.

There were 32 children upon the street; 4 of these were deformed in the legs.

2 of these were curved laterally outwards; 1 was nill-kneed, and "shachly" in walking; 1, the tibia was laterally curved outwards in one leg. There was 1 child deformed in the legs in 8.

Oatmeal is much used in porridge, and some families bake oatmeal cakes. This is amongst the Scottish portion of the community. But amongst the Irish portion there is little oatmeal used, and the deformities are more frequent amongst the children of the latter than amongst the former.

23rd July, 1883.

Smith Street, Whiteinch, 12 noon. Ages of the children, from 3 to 7 years.

There were 20 children upon the street; 8 of these were more or less deformed in the legs.

4 of these children were much curved inwards in the middle of the legs; 1, the legs were slightly curved inwards in the middle; 2, the legs were curved outwards from the knee downwards; 1 was nill-kneed. 1 child deformed in the legs in every $2\frac{1}{2}$ children.

There are 3 tons of sugar sold for every ton of oatmeal.

24th July, 1883.

White Street, Govan, 1 p.m.

There were 11 children upon the street; 4 of these were deformed in the legs, in which the centres of the legs were curved laterally outwards. There is 1 child deformed in $2\frac{3}{4}$ children.

There are 4 tons of sugar sold for 1 ton of oatmeal.

Victoria Street, Govan, 5 p.m. Ages of children, from 3 to 7 years.

There were 32 children upon the street; 8 of these were more or less deformed in the legs.

1 of these children was much curved anteriorly in the middle of the legs; the others were nill-kneed, and laterally curved outwards. There is 1 child deformed in the legs in every $2\frac{6}{8}$.

There are 4 tons of sugar sold for 1 ton of oatmeal.

25th July, 1883.

Carmichael Street, Govan, 5.30 p.m. Ages of children, from 3 to 7 years.

There were 9 children upon the street; 2 of these were deformed in the legs.

1 of the children the legs were much curved anteriorly; 1, the legs were badly nill-kneed, and slightly curved anteriorly about the middle of the legs, with large abdomen. There is 1 child deformed in the legs for every $4\frac{1}{2}$.

30th July, 1883.

Graham Street, Airdrie, 4.5 p.m. Ages of children, from 3 to 7 years.

There were 16 children upon the street; 3 of these were deformed in the legs.

1 of the children was nill-kneed and weakly in the back; 1, the legs were badly curved laterally outwards; 1, the legs were curved anteriorly about the middle. There is 1 child deformed in the legs in every $5\frac{1}{3}$.

There are 6 tons of sugar sold for 1 ton of oatmeal.

31st July, 1883.

Whifflet, 11.30 a.m. Age of children, from 3 to 7 years.

There were 16 children upon the street.

There were 3 of these children much curved laterally and outwardly. The children in this locality are otherwise strong and healthy looking. There is 1 child deformed in the legs in every $5\frac{1}{3}$.

There are 3 tons of sugar sold for 1 ton of oatmeal.

3rd August, 1883.

Renton, 10.45 a.m. Ages of the children, from 3 to 7 years.

There were 37 children upon the street; 3 of these children were deformed in the legs.

1 of the children the legs were slightly curved laterally outwards; 1 was nill-kneed, and weakly in the pelvic region; 1, the legs were curved laterally outwards near the base. There is 1 child deformed in the legs in $12\frac{1}{3}$.

Oatmeal is daily used, unless by the Irish portion of the community.

3rd August, 1883.

Dumbarton, Main Street, 12 noon. Ages of children, from 3 to 7 years.

There were 12 children upon the street; 2 of these were deformed in the legs.

In 1 of the children the legs were slightly curved anteriorly and laterally in the middle; 1, the legs were curved anteriorly, and the os calcis is much enlarged. There is 1 child in 6 deformed in the legs.

There are 2½ tons of sugar sold for 1 ton of oatmeal.

4h August, 1883.

Larkhall, 1 p.m. Ages of the children from 3 to 7 years.

There were 30 children upon the street: 3 of these were deformed in the legs.

1 of the children the legs are curved laterally outwards; 1, the legs are weakly and "shachly;" 1 is nill-kneed. There is 1 child deformed in 10.

Oatmeal is used by the Scotch in porridge and cakes, but not by the Irish.

There were 120 children upon the street from 7 to 14 years, 1 of these was nill-kneed.

18th August, 1883.

Tobago Street, Calton, Glasgow, 12.30 p.m. Ages of children, from 3 to 7 years.

There were 9 children upon the street; 3 of these were deformed in the legs.

1 of the children was shachly-legged and generally weakly; 1, the legs, were curved laterally outwards a little below the knee, the curved portion was about 3 inches long; 1, the legs were curved anteriorly in the middle. There is 1 child deformed in the legs in 3.

Oatmeal is little used in this locality.

15th August, 1883.

Claythorn Street, Calton, 12.45 p.m. Age of children, from 3 to 7 years.

There were 21 children upon the street; 5 of these were deformed in the legs. 1 of the children the legs are much curved inwards below the knee, and outwards immediately above the os calcis, the tarsi are unusually large; 1, the left leg is much curved inwards; 2, the legs are curved laterally outwards; 1, the legs are curved anteriorly at the middle. There is 1 child deformed in the legs in every 4⅕.

Oatmeal is little used in this locality.

Bankier Street, off Claythorn Street, Calton, 12.50 p.m. Age of children from 3 to 7 years.

There were 9 children upon the street; 3 of these were deformed in the legs.

1 of these children the right leg was curved laterally outwards, and much curved inwards below the knee in left leg; 1, the legs were curved anteriorly a little above the ankle, and in-kneed and wriggled much in walking; 1, badly nill-kneed, abdomen large, and pelvic region much protruded. There is 1 child deformed in every 3. Oatmeal is little used.

17th August, 1883.

Lanark, 3.15 p.m. Ages of children, from 3 to 7 years.

There were 22 children upon the street; 3 of these were deformed in the legs.

1 of the children was nill-kneed in right leg, and curved laterally outwards in left leg; 1 was nill-kneed; 1, the legs were curved anteriorly. There is 1 child deformed in every $7\frac{1}{3}$.

Oatmeal is not so much used as it was a few years ago.

18th August, 1883.

Kilmarnock, High Street, 12 noon. Ages of children, from 3 to 7 years.

There were 45 children upon the street; 3 of these were deformed in the legs.

1 of the children the legs were laterally curved outwards; 1 was nill-kneed in left leg, and curved laterally outwards in right leg; 1, the legs are curved anteriorly in the middle of the legs. There is 1 child in 15 deformed in the legs.

Oatmeal is daily used, unless amongst the Irish portion of the population, and it is principally amongst these that the deformities are found.

23rd August, 1883.

Copeland Road, Govan, 6.30 p.m. Ages of children, from 7 to 14 years.

There were 50 children upon the road, and there was 1 boy curved outwards in the middle of the legs; his legs were altogether weakly.

11th September, 1883.

Bellshill, West-end, 2 p.m. Ages of children, from 3 to 7 years.

There were 27 children upon the street. There was 1 child slightly deformed.

Oatmeal is largely used. 1 child deformed in 27.

Bellshill, East-end, 3 p.m. Ages of children, from 3 to 7 years.

There were 12 children upon the street; 3 of the children were slightly deformed in the legs. 1 child deformed in 3.

Oatmeal is little used. The population principally consists of English and Irish.

27th September, 1883.

Motherwell, Merry Street, 12 noon. Ages of children, from 3 to 7 years.

There were 22 children upon the street. There were 5 children deformed in the legs.

2 of the children the legs were curved anteriorly in the middle; 1 nill-kneed; 2, the legs were laterally curved outwards. There is 1 child deformed in $5\frac{2}{5}$.

Motherwell, King Street, 12.30 p.m. Ages of children, from 3 to 7 years.

There were 14 children upon the street; 3 of these were deformed in the legs.

1 of the children was nill-kneed; 1, the legs were curved laterally outwards; 1, the legs were curved anteriorly. There is 1 child deformed in $4\frac{3}{4}$.

There were 124 children upon the street. Age, 7 to 14 years.

1 of these the right leg was curved inwards.

Oatmeal is little used.

29th October, 1883.

Motherwell, 12.30 p.m. Ages of children, from 3 to 7 years.

There were 9 children upon the street. There were 2 of these deformed in the legs.

1 of the children the legs were much curved laterally outwards below the knee; 1, the right leg is badly nill-kneed, and the left

leg is curved anteriorly. There is 1 child deformed in the legs in $4\frac{1}{2}$.

Ages of children, from 7 to 14 years.

There are 4 tons of sugar sold for 1 ton of oatmeal.

1st November, 1883.

Huntingdon Place, St. Rollox, Glasgow, 1 p.m. Ages of children, from 3 to 7 years.

In this place every second child is deformed, representing every form of deformity.

Ages from 7 to 14.

There were 51 children upon the street, and 1 girl, about 10 years of age, the legs were slightly curved anteriorly.

Oatmeal is seldom sold in this locality.

6th November, 1883.

Strathaven, North side of Town, 3 p.m. Ages of children, from 3 to 7 years.

There were 6 children upon the street; 2 of these were deformed in the legs.

1 of the children the legs were badly curved laterally; 1 was nill-kneed and weakly in spine. There is 1 child deformed in 3.

There are 4 tons of sugar sold for 1 ton of oatmeal.

29th November, 1883.

St. James' Street, Kingston, Glasgow, 11.30 a.m. Ages of children, from 3 to 7 years.

There were 14 children upon the street; 5 of these were deformed in the legs.

3 of the children the legs were curved laterally outwards; 1, the right leg was curved posteriorly; 1 slightly knock-kneed, legs weakly. There is 1 child deformed in $2\frac{3}{4}$.

Oatmeal is little used.

Crossford, near Lanark.

There has not been a native child deformed in this village for the last 40 years. There was 1 deformed child brought into the village about 4 years ago, whose parents were Irish.

Oatmeal is used twice daily.

Stornoway, Outer Hebrides. I have been unable to learn of a single case of deformed legs in that town.

Oatmeal is much used.

Islay. Dr. M'Indeor informs me that there has not been a native child deformed in the legs for 30 years. About 28 years ago there was a delicate child, with deformed limbs, brought from Glasgow to Islay. The parents were poor and were obliged to use oatmeal, at least twice daily. Their child not only regained health, but the legs became normal, and he is now as well formed in the legs as any man in Islay.

Oatmeal is used in Islay, at least twice daily.

The author then gave an elaborate account of the structure and nutrition of bone, and of the pathology of rickets, quoting largely from *Gamgee's Physiological Chemistry*, Vol. I., and *Quain's Anatomy*, ninth edition. He continued:—

In addition to the influence of the kind of food and water used by the labouring classes, other influences have been supposed to operate in the production of rickets, such as the effects of habitually breathing a vitiated atmosphere, living in houses built on a damp soil, careless nursing, &c. The author proceeded to discuss several of these influences.

Effects of Impure Air.—Some have asserted that the great increase in the deformities of the limbs of the children is largely due to impure air. Such have some grounds for their opinion. During my investigations I have found that in those localities where the children are daily inhaling air vitiated with every impurity these deformities are of a very aggravated nature. In addition, the skin of these children indicates an unhealthy condition, and impresses upon the observer the conviction that there is an intense struggle for life, and that it is only the strongest of them that we can reasonably hope will survive. Even amongst these, in after life, the impress of their early surrounding is ever apparent. We must, however, seek some other cause or causes to account for this abnormal condition, as in several of the localities enumerated there is no want of pure air. In Caledonia Road and in some of the country villages the houses they inhabit are only built on the one side of the road or street. Under such conditions there is nothing to interfere with a constant supply of pure air.

Effects of Damp Sub-soil.—Some have suggested that the damp sub-soil may have much to do in inducing such deformities.

I believe that the sub-soil has a great influence on the healthy upbringing of children, more especially in many of these speculative-built properties, where the sub-soil is cold boulder clay. The foundations of many of these houses are often not more than from 12 to 15 inches below the surface; necessarily, the ground flats are always damp, and the exhalations of the damp ground flat penetrate and permeate the whole property. The atmosphere is thus vitiated, and the children are exposed to and inhale the sour, damp air, impregnated with the concomitant impurities of such untenantable dwellings.

Effects of Bad Nursing.—Some have suggested careless mothers and bad nursing as the cause. This may be, and I believe is, the cause of not only many of these deformities, but is also the root and source of hundreds of shattered and ruined constitutions that are from year to year thrust as burdens upon society. It is, however, only in a limited number of cases that we can trace these abnormal conditions to the mother's neglect. Improper nursing by no means accounts for all; the cause is deeper rooted, because there are hundreds of children deformed whose mothers are attentive and well disposed, to whom their deformed offspring is a great source of grief. If anyone wishes assurance on this point let them attend the Royal Infirmary on any of Dr. MacEwen's receiving days, and there they will find mothers whose external aspect indicates thrift and care in a marked degree, but in whose faces may be detected internal emotions of a pronounced character. Every word emanating from the doctor's lips is weighed, and every look watched with an anxiety that tells plainly that if she could mitigate or arrest this sad condition no effort would be spared to attain such a wished-for result.

Personal inquiry as to food used in a working man's family.—In order that we may more fully realise the importance of the home influence upon this sad disease, let us go to their homes and see their surroundings, and learn how these children are being cared for, and what kind of food they are in the habit of using. As a fair representation, I have selected three localities—two in Glasgow and one in a country village. The first is in Claythorn Street, Calton, where I entered the home of one of these deformed children. The mother was actively engaged with her household duties. I introduced myself, apologising for thus obtruding, and assuring her that my visit was for the purpose of collecting facts regarding these deformities that are becoming so common in the

limbs of children, and which I was sorry to see in one of her little ones; and I politely requested her to aid me by giving any information she could, and to answer a few questions regarding the food in daily use. I was fortunate in my selection, and I was met with a willing and ready response from a mother whose children were clean, and whose house indicated thrift and carefulness.

Q. What age is your husband?—A. He is 26 years past.

Q. How long have you been married?—A. Seven years.

Q. How many children have you?—A. Three.

Q. Is your husband about the same age as yourself?—A. He is about a year older.

Q. What does he work at?—A. He is working in a ship-yard in the west end; he was working in a mill before, but the mill was burnt and he then went to the ship-yard.

Q. Were you employed in any public work before you were married?—A. Yes, I wrought in the same mill.

Q. When did you begin work in the morning?—A. Six o'clock.

Q. How long did you get for your meals?—A. An hour.

Q. How far had you to go for your food?—A. About a mile.

Q. With only an hour, and having nearly a mile to walk, you could not have much time to cook food?—A. No; we had only as much time as to boil a little water to mask a cup of tea.

Q. What kind of bread did you use chiefly?—A. Loaf-bread.

Q. Was your husband's food similar to your own?—A. He had a much longer road to go, and he brought some loaf-bread and butter with him, and took his breakfast inside the gate.

Q. What did he get for dinner?—A. He sometimes went up to the cook-shop and got a penny bowl of broth, with potatoes and potted-head, and sometimes he brought as much loaf-bread and tea as did for his dinner too.

Q. What did you take for dinner?—A. Sometimes we got potatoes and ham, and at other times we got tea.

Q. What did you get for supper?—A. We had tea, with loaf-bread and ham, or sometimes fish.

Q. Since you were married, how does your husband do for his food, seeing the distance is so great he will not get home for any of his meals till evening?—A. He gets a cup of coffee before he leaves in the morning about a quarter-past five, and takes a piece and cold tea with him for his breakfast; for dinner he goes to the Cooking Depot and gets a bowl of broth, with potatoes and meat, and when he comes home I always plan to have something as nice as I can give him to his tea.

Q. As for yourself and children, what do you prepare for breakfast?—A. I usually give them a cup of tea and a piece of loaf, spread whiles with butter and sometimes with jelly.

Q. And for dinner what do you usually give them?—A. I often give them potatoes and meat (butcher meat), but on washing-days, or when I am cleaning, I give them a jelly-piece for a "pit-ower."

Q. Do you ever make porridge for them?—A. Well, I have sometimes tried them with porridge, but none of them will take them, their hearts turn at them, and I just give them a jelly-piece to coax them to eat.

Q. Do you never use Oatmeal Cakes?—A. Sometimes I buy a penny farle, but they are so hard that none of us can eat them.

Q. When did the oldest child's legs become deformed?—A. Her legs were quite straight and a nice bairn till she had the measles and whooping-cough, after that she took a dwining and was dowsie for a long time, then her legs got weakly and grew bent as you see them.

Q. Are the other two children healthy and strong?—A. The youngest is a nice, healthy bairn; but the wee laddie—the second—has been dwining since he had the measles, and I often give him a jelly-piece to coax him to eat.

Such is a brief outline of answers given to a few of the questions put to a highly-respectable mother, who seemed to have for a husband a well-doing working man—indeed, their home had all the indications of thrift, and that their earnings were spent to the best advantage as far as their knowledge went.

Regarding the other two cases referred to, I need not go over a similar series of questions and answers. In general, the answers were much alike.

The other City case referred to is in Oatlands, South Side. This family live in one of the speculative-built properties; the houses are far from being what they ought to be; the tenants are no better—indeed, squalor and misery reign supreme. In this home oatmeal is never used; wheaten bread, if it can be called bread, and potatoes are the principal articles of diet. The children are not only deformed in the limbs, but the general appearance is unhealthy—their skins are dry and have a yellowish-grey colour.

The other case referred to in the country is at Carfin, where there is no want of fresh air. The houses are built on the side of the public highway, and surrounded by green fields. The men are employed in the coal mines, and are usually absent from their homes from early morning till the afternoon. The house entered was simply a den of squalor and misery; there was scarcely an

article of furniture in it. The mother was untidy, and the children were unwashed, and all indicated that every feeling of thrift and well-being had been crushed out of the inmates. Oatmeal is little used; tea and wheaten bread are the principal articles of diet, varied with potatoes.

Such is a brief outline of the conditions of many of the homes out of which these poor, helpless, deformed, little fellow-creatures come—they are simply nurseries of disease.

Why do working people use improper Food?—The question has been put to me—Do not many of those people believe that as articles of diet, tea and wheaten bread are cheaper, and in consequence of their ignorance of the laws that regulate the healthy upbringing of children, do they not use these substitutes for the sake of economy? My answer to such a question is—I do believe that some do use such as food on economic grounds; but with others, no such prudential thoughts pass through their minds.

Well, but many say their children have a dislike to porridge, and will not take it. Whether they dislike it or not very much depends upon the care the mother has bestowed upon the teaching her children what and how to take. There is a natural inclination in all children to grasp all kinds of food that is conveyed to the mouth. Indeed, in infancy, children attempt to grasp the mamma of the mother; and if a child is allowed, before a taste for porridge is acquired, to sup by itself, it is quite a common occurrence to see the child attempting to grasp the porridge to convey it to the mouth. Failing to satisfy its own desires, it is no uncommon occurrence to see the little one thrust all from it in disgust.

Let the mother, however, cook the porridge properly, and teach the child to sup it before it becomes cold, and there is no fear of the child not relishing it. But, in order to acquire a knowledge of cooking simple, plain food properly, she must be taught in her early days. I venture to think that if there were more attention paid to the nutrient properties of diet, and greater care exercised in the cooking of simple, plain food, there would be fewer deformed children than are now seen in our midst. And I conceive that if the results of the lately-formed cooking schools were at all commensurate with the intention of the generous founders, instead of teaching the pupils to cook pastries and such like indigestible dishes, if greater attention were paid to the proper method of cooking the simple and more nutritious diet, that is not only more wholesome,

but is also cheaper, and more compatible with the wants of the body, such institutions would become a boon both to present and future generations. More I do not wish to say on that point, but rather leave that department in charge of our School Board authorities and cooking schools.

Cost of food of working people: a comparison.—In order, however, that this may be put on as clear a basis as our knowledge will admit of, let me compare the relative cost of each.

Take, for example, a family of three children. Let us cut a quartern, or two-pound loaf into seven parts, the cost of which is $3\frac{1}{2}$d., which is $\frac{1}{2}$d. per part; add to each $\frac{1}{2}$d. worth of butter or jelly; give to each of the three children one of these parts, costing 1d. each, or 3d. in all; allow $\frac{1}{2}$d. for tea and $\frac{1}{2}$d. for sugar, 1d., or 4d. for the meal for the three children, or $1\frac{1}{3}$d. for each.

Now, instead of tea and bread, let us try what will be the cost of a basin of good porridge and milk.

Take one pound of oatmeal, which costs 2d.; boil it well in water, with a little salt added; when sufficiently boiled it will fill eight small basins, costing $\frac{1}{4}$d. each. Give to each of the children a $\frac{1}{2}$d. worth of milk; costing in all $\frac{3}{4}$d. for each child's meal. We have thus a much more nutritious meal at an average cost of $\frac{3}{4}$d. than we have in the former at an average cost of $1\frac{1}{3}$d., so that the more nutritious and more easily digested of the two diets is the cheapest.

Such is but a brief outline of what takes place from day to day and year to year. If time permitted, I might have adduced hundreds of cases bearing testimony to similar conditions.

During my investigations as to the extent of these deformities I have, as far as possible, sought to know what kind of food is used in the different localities, and I have arrived at the following conclusions:—

(1) In proportion to the use or disuse of plain wholesome food there is a proportionate increase or decrease of rickets.

(2) In those localities where white wheaten bread, sugar, and tea have taken the place of the old nutritious porridge and milk for children's food rickets is prevalent. Indeed, in some of these localities every second child between the ages of 3 and 7 is deformed.

(3) Where oatmeal is largely used the disease is seldom heard of. In Crossford, Lanarkshire, that article of diet is used both morning and evening, and there has not been a single native

case for fully forty years. We have found similar testimony in the West Highlands—in Lewis, Skye, Mull, Islay, &c. Where oatmeal forms the staple article of diet, I am informed that the biggest boned and broadest chested men are found. (This, I understand, refers more particularly to Aberdeenshire and Morayshire, where the agricultural classes use oatmeal as their chief, almost their only diet.)

(4) Where oatmeal is seldom or never used we have found that the children are deformed, and in many cases they are helpless objects, unfit to follow any of the ordinary avocations of life.

With such startling conclusions before us, I venture to say that it behoves every well-wisher of humanity to lend his aid, and, if possible, suggest remedial measures.

Author's Theory as to probable Pathological Cause.—The question may now be asked—Is it an excess of acid that destroys in the blood the constituent elements of which the bones are composed? Gamgee (*Loc. Cit.*, p. 283) regards such an opinion as crude.

In the rough experiments formerly referred to, we found that the bones of the sheep, ox, pig, and human being, after immersion for a given time, were more or less affected, and that in the vessels in which the larger proportion of sugar was used the degrading action was more active, and lime salts of the bones were dissolved, and held in chemical suspension. Now, in all the farinaceous foods there are certain constituents of these foods that are converted into sugar in the alimentary canal. If, in addition to these normal and properly-adjusted constituents, we introduce daily an additional quantity of sugar or any other substance, is it unreasonable to suppose that such will more or less influence the blood? If there is an excess of lime salts, these are secreted in some part of the body; and if there is an excess of acidulous matter we would naturally expect such to act as an irritant, which would tend to prevent the deposition in the bones of the molecules of calcareous matter; further, we would expect the dissolution of the already deposited calcareous ingredients from the same cause; and, if we could only realise how delicate are the chemical combinations of the matter of which food is composed, and what are the properly-adjusted equivalent parts in solution in the blood, then would we more accurately realise the minute chemical changes that are produced by the daily introduction into the body of an undue proportion of either tannic or acetic acids

from the excessive use of wheaten bread, sugar, and tea. In this, as in other results of natural law, all changes are brought about by infinitesimal and inappreciable degrees. It is not the torrent of rushing waters that melts the mountain track; the infinitesimal, soft, pellucid rain-drop contains all the elements of dissolution; yea, even the most refractory minerals and metals yield to this invisible, yet majestic, power. If it were possible that man, aided by the latest discovery of Science, could discover the chemical combinations of the matters which form blood, or could he follow that silent, living stream rushing through the arterial passages; could he note their differentiation, to be again differentiated, and re-differentiated again and again; could he follow the flow of blood through that labyrinth of intricate ramifications of the body, with all the constituent elements that are required for the building of the frame, silently freeing itself of the atoms of matter, returning to be recuperated, to again emerge on its vital mission; and could he realise that in each half-minute of time the whole volume of blood may be said to emerge from, and to return and pass through the heart; could he realize how delicate these molecules of matter must be, how minute the proportion, and how exquisite the adaptation; then he would see how infinitesimal changes in the composition of the blood, may produce very great changes in the nutrition of tissue. Could man's intellect be thus aided, and thus brought into the presence of the immeasurable—such I venture to think would provoke reflection. He would realize that, let him but alter any one of these equivalents, an effect would be produced so minute that even aid with all appliances of modern invention would fail to detect the change, and yet the ceaseless stream of blood would carry the effect through all the ramifications of the bones. Alter any of Nature's adjusted proportions, and all require to be re-adjusted. If the blood has but added to it even an infinitesimal amount of acidulous matter more than is required to meet the demand, is it not possible such may seriously affect nutrition? May not the acid incorporate itself with other constituents of the blood, and alter this fluid, which will then be carried by its circulation throughout the countless canals of the bones—canals so minute that it requires the high magnifying powers of the microscope to define their existence, yet each of these canals are surrounded by laminæ, and the constituents of the laminæ are formed by the blood. It needs no language of mine to convey

the simple truth that any kind of acid must have a more or less dissolving action upon the calcareous ingredients of the blood, and thus not only prevent their deposition, but also have an absorbing influence upon previously secreted earthy matters; and in proportion to its irritant and dissolving action is this metamorphism of the constituents brought about. We see the results, yet we cannot trace the transmutation of the elements of food; we know such goes on with mathematically-adjusted precision of detail, and that any interference with the quality of the blood must interfere with the nutrition not merely of the bones, but of all the tissues of the body.

XXIV.—*The Life and Works of Thomas Graham, D.C.L., F.R.S., Illustrated by 64 unpublished Letters.* Prepared for the Graham Lecture Committee of the Glasgow Philosophical Society by ROBERT ANGUS SMITH, LL.D., F.R.S. Edited by J. J. COLEMAN, F.I.C., F.C.S.

THE Graham Medal and Lecture Fund was established in 1878 by the leading manufacturing chemists of Glasgow subscribing a sufficient amount of money, the annual interest of which was to be employed by the Chemical Section of the Philosophical Society of Glasgow in the encouragement of research, the name of Graham being coupled with this fund on account of his being a Glasgow man and a great chemist, whose aims and methods are worthy of imitation.

The first Graham Lecture was accordingly devoted to the life of Graham as an investigator, and was delivered in 1879 by Mr. Chandler Roberts, F.R.S.

The Committee did not think it then necessary to devote further lectures exclusively to the life and work of Graham, but it was pointed out to them by the late Dr. James Young of Kelly that a full life of Thomas Graham had never been written, and that a large collection of his private letters were in the hands of Dr. Angus Smith, awaiting a convenient opportunity for publication. Communication was then made with Dr. Angus Smith, who expressed an opinion that extracts from these letters would be of sufficient interest to justify the Committee in adopting them as the basis of the second Graham Lecture, and that he would be pleased to deliver this lecture for the Committee.

A letter was received by us on the 2nd February, 1884, in which Dr. Angus Smith says:—"As to the Graham Lecture, I shall endeavour to describe it. It will consist of—*First*, Preface about Glasgow—fragmentary, very fragmentary. *Second*, An introduction, trying to describe Graham's surroundings in Glasgow, also very fragmentary. *Third*, A long series of extracts from letters by Graham, from his earliest college days to his later years. This will constitute the pith and novelty of the paper, and it is this which I desire to have published in connection with his writings as abridged by me. *Fourth*, The abridgment of Graham's writings. It will not be in the artistic form of a lecture, but it will contain matter to be preserved, and it will be as it stands a life of Graham,

fragmentary, it is true, but capable of being added to, and the additions I may be able to make as it is passing through the press."

The lecture was fixed for the 20th February, 1884, but the hand of death was already upon Dr. Angus Smith,* and, amid much feebleness and effort, the MS. was transmitted to Glasgow a few days before, and read to the Society by Professor Ferguson. Dr. Angus Smith was born only twelve years after Graham, and some of the last moments of the busy life of Dr. Angus Smith were employed in putting together these memorials of his early friend, who was one of the most distinguished workers in chemical science of the first half of the nineteenth century, and amongst whom Dr. Angus Smith himself was not the least notable.

The fragmentary notes which Dr. Smith prepared for the introduction to his lecture contain references to the origin of Glasgow as a community 1200 years ago; the five hundred years of darkness between St. Kentigern's death and the establishment of the University by the then Pope in 1450-1 ; and the string of eminent men who from the University disseminated their influence upon surrounding society in succeeding centuries, culminating at the commencement of the present century in the advent of Thomas Thomson, the great expounder of Dalton and teacher of Graham.

Thomas Graham was born in Glasgow, 21st December, 1805—Faraday, whom he is worthy to be compared with, being then fourteen years old—and went first to a preparatory school in 1811, thence to the Glasgow High School in 1814, where he studied classics under Dr. Dymock and Dr. Chrystal. He subsequently studied at the University from 1819 to 1826, taking his degree as M.A. in 1826.

His taste for chemistry was very early developed, even before he left the nursery ; his amusements when 6 or 7 years old were making gas in tobacco pipes, making eggs move with quicksilver, and other little tricks of the kind.

Graham's father was a merchant of good position in Glasgow, and the boy was originally intended for the church. His strong predilections for a scientific career, however, caused him to shape out a path for himself, much to the grief of his father, who, probably not understanding the aims and scope of science, was prejudiced in his judgment. That such was the case was proved by the sequel. But although Graham eventually became possessor of his father's property and a comparatively rich man, in these

* Dr. Angus Smith died 11th April, 1884.

early days he was poor; but his letters at this time to his mother and sister Margeret show a gentle and courageous spirit, sustained by lofty ambition, which make them as literary productions peculiarly interesting.

Immediately after obtaining his degree at Glasgow in 1826 he went to Edinburgh, where he pursued his scientific studies under Dr. Hope, and enjoyed the friendship of Professor Leslie.

One of his earliest letters from Edinburgh, dated June 10, 1826, contains the following curious sentences:—

"To Mrs. Graham.

"From Edinburgh, 10th June, 1826.

"—— The Professors here are all at logger-heads with each other. Leslie calls Hope in his class-room 'the showman in the other corner,' while Dr. Hamilton has just received £500 from Hope for defamation."

Graham's letters dated from Edinburgh are here printed in the order arranged by Dr. Angus Smith, with a few connecting remarks by the Editor.

Edinburgh, 22nd June, 1826.

My Dear Mother,—I must request Henry to deliver the enclosed letters. The only one which he is not acquainted with is Muir's. Let it be handed in to Muir's warehouse, which is I believe under Rennie's school. It is requesting Muir to send down to Henry the Chemical Society Minute Book, as I have at last succeeded in establishing a similar institution in Edinburgh. If Henry gets the Minute Book sent down to him, which I am rather afraid he will not, as Steel has it probably away with him, he will be so good as to send it to me by coach before the end of next week. It will be too bulky to go into the office parcel. I hope you will be merciful to me in not answering your letters quickly, as I singly have such a number of correspondents, and have before me a vast deal of writing work. I opened the new Chemical Society last Saturday with an essay, and am appointed to deliver soon in the Hunterian. I am quite well-known here now. My best respects to Grandmother and Aunt. Will you make my correspondents be more particular in telling how grandmother is getting on.

I remain,

Dear Mother,

Yours sincerely,

THO. GRAHAM.

Edinburgh, 7th July, 1826.

My Dear Margaret,—I am much obliged to you for your long and elaborate epistle. Till this moment I have not had the smallest leisure to answer it. My first and introductory essay in the Hunterian went off with great *eclat.* On the motion of Dr. Brown (the poet of Stirling), a vote of thanks was given for it. This must be a very good thing, if we are to judge of it from its rarity, as it is the first time which it has occurred in the Hunterian. The best part of the vote was "and that Mr. G—— be solicited to make his essay public"! However, I have no intention of publishing till I accumulate matter, not for an article, not for a pamphlet, but for a book—God knows when that will be.

As for Edinburgh news, I can send you very little. Hamilton, the bookseller, says that Constable's affairs are very bad—that he has really been in an insolvent state for the last six or seven years. For several years he has been paying at the rate of £5,000 a year for mere discounts—a circumstance which of itself was enough soon to have ruined him. The editors of the *Edinburgh Medical Journal* and *Jameson's Scientific Journal* have deserted him, and taken to other publishers. His *Edinburgh Monthly Magazine* has been given up. A composition of 3s. 6d. in the £ is talked of. Sir Walter Scott will get on; he has been made King's printer—a situation worth £3,000 a year, chiefly in salary. Sir Walter must have been rather a calculating genius. It turns out that he was almost sole proprietor in the printing establishment of James Ballantyne & Co., who have failed; so that he intended not only to profit by writing the novels, but also to have a good share in the profits of printing them. Ballantyne was little more than his servant. I have not had time to read "Woodstock" yet. Sir Walter has in some measure satisfied the cravings of his creditors by binding over to them "Napoleon," and several forthcoming novels. The estate of Abbotsford is really not Sir Walter's, it is his son's; it was bought with Lady Scott's money, who had £70,000, and settled upon *her* heirs, so that it is in no danger. Lady Scott was a Frenchwoman.

Bentress is going to Paris in April next; he confesses that his estate is worth £1,500 a year. He and I were down at the glass-house getting instruments constructed. He has been so often there about his *Gravimeter* that he is as well known (he says) as a pickpocket. We had glorious fun the night he brought out his

instrument in the Hunterian—he was so afraid of a public appearance. I followed, and eulogised his instrument. In return, when he heard that I was to read on "Liquidity," he got out all books possible on the subject, and was telling MacDowal that he wished to God that he would be able to make a speech for Gra-ham (two syllables). . . . You may assure Bell that the washerwomen are such blockheads here that they did not put an atom of starch into my shirts—horrible! horrible! . . . We have had several showers here, and even a wet day or two, but the rain has scarcely made a sensible impression.

How are the Miss Campbells? How are all the Glasgow young ladies? Alas, the want of them is felt most sensibly here; as Miss Brown (Mitchell's landlady) says, the gentlemen turn savages when they go out to the West Indies for want of them. Alas, that I should become

Your most loving *Indian Savage*,

THO. GRAHAM.

Edinburgh, 1st August, 1826.

MY DEAR MOTHER,—I had not seen the *Annals of Philosophy* since I came to Edinburgh, so that I was not aware, till congratulated upon the circumstance by him (Johnston) that a certain paper of mine had been republished in the number of that work for July. I have sent a copy for you. The *Annals of Philosophy* is a London publication, and is the leading scientific journal of the country. It is published monthly, and is 2/6 a number. You will find in the number enclosed articles by Dr. Christison, a Professor in the College here, by Mr. Christie, a Professor at Woolwich, by Dr. Hugh Colquhoun, Professor Thomson's nephew, an ingenious young chemist, by Sir H. Davy, page 62, etc; it is therefore a good introduction. I also trouble you with the inaugural discourse of a young M.D., a friend of mine. You need not care although his lairdship [Graham's father] see the foregoing.

Edinburgh, 21st September, 1826.

MY DEAR MARGARET,—I have been writing a good deal of late and experimenting too—although from Langstaff's absence and

other circumstances, not in the laboratory. In the investigations, however, in which I have been been latterly engaged, a laboratory is by no means necessary. My essay in the *Annals* seems to have had some effect, as it will appear from a quotation which I am about to make from the No. of that Periodical for the present month, p. 100—the author is a Mr. Bailey, and he is criticising Dr. Hugh Colquhoun's paper "The accurate reasoning of Mr. Graham, I may also remark, in his observations on the absorption of gases by liquids (quoted in the same number of the *Annals* in which Dr. Colquhoun's paper appears), as well as the experimental evidence he cites, is entirely favourable to this view, etc."

It may be proper to mention that that essay forms a part, and only a small part, of a much greater investigation in which I am engaged, which I hope will all be equally successful. Perhaps in a month or two I will have something additional in the *Annals.* It is this circumstance which makes me less caring about being baulked at the Mechanics' Institution. Had I got that situation, the overwhelming labour which would have accompanied the proper and successful discharge of its duties, would have been amply sufficient of itself—a labour, too, which would be of very little use to myself—whereas the labour in which I am at present engaged in following out my theoretic speculations, may eventually be even more productive and profitable—certainly more honourable and productive of scientific distinction. Clark, my antagonist, has never got the length of the *Annals.*

Edinburgh, 11th Oct., 1826.

MY DEAR MOTHER,—The basket has been delayed from day to day in the daily expectation of the journal which accompanies it, and which contains another article, as you will see by the contents. The journal was printed in London ten or eleven days ago, but owing to a passage, per smack, of nine days, did not arrive here till to-day. The next number will probably contain a notice of a curious discovery of Miss C. and me in Baking. The present article, although short, is one of considerable importance. There is nothing that I wish more than that somebody should oppose the theory which it contains, as a discussion of that kind is the very thing to make one known.

Before the laird's burst of eloquence arrived—conceiving that I was fairly set upon my own pins—I had commenced a little chemical work, for which I think there is a call. I can give you here no more than its title page.

THE LANGUAGE OF CHEMISTRY:

OR A

DEFINITION OF THE TERM OF THE SCIENCE,

SYSTEMATICALLY ARRANGED, DEVELOPING ITS PRINCIPLES

AND OBJECT.

Edinburgh, Oct. 15, 1826.

MY DEAR MOTHER,—My operations have been interrupted for two or three days. I find a room, which Miss Cameron occupies at night as a sleeping room, and which is otherwise unoccupied, forms a very good laboratory for the experiments in which I am engaged, and likely to be engaged for a considerable time. They are doing very well.

Edinburgh, Nov. 7, 1826.

MY DEAR MOTHER,—I send you, by Mr. Stirling, another number of the *Annals* having a short notice of mine in it. I am glad to hear by him that you are all well. You could not be better than we are here. Did Mr. A. Mitchell call with my letter and Miss C.'s, which was worth half a dozen of mine?

The students are flocking in here in great numbers, but no classes have opened as yet, except the medical. My laboratory is getting on quite to my liking.

"The Language of Chemistry" has been laid on the shelf for some time. We are tiring to death here for want of letters from Cloverbank. At the beginning of next week be so good as to send Bell down to Howie's, the carriers, for a tin box, carriage paid, which I hope will contain a more faithful and full representation of matters than this scrawl.—I am, with much respect,

Yours affectionately,

THO. GRAHAM

Edinburgh, 20th November, 1826.

My Dear Mother,—Although I have not achieved a great-coat, yet I am rather comfortably accoutred in a pair of "gentleman's lamb's-wool pantaloons," *alias* long-legged worsted drawers. My particular studies are going on very favourably, although I was obliged to lay out a little in furnishing my home laboratory, yet it will be easy to make it all up.

The town is filling very quickly. All the classes, nearly, having opened, and the Courts having sat down for the winter. As for myself, I neither see much of the bustle nor care for it. The more secluded I keep myself from company till I have acquired some standing in science the better. The lassie here is very convenient for such interruptions, for whenever she knows that I am engaged she takes it upon herself to say that I am from home —very much to my satisfaction in general.

Edinburgh, 20th November, 1826.

My Dear Margaret,—Mr. Dunn, a philosophical instrument maker, cheated me of the opportunity of having an article in the next number of the *Annals*, by making me wait for ten days or a fortnight for some very minute weights which he was making for me and which were necessary. Professor Brande has done me the honour of giving a very favourable account of my first article in his *Quarterly Journal of Science* for October, but which I did not see till a few days ago accidentally upon the table of the Writers to the Signet Library. The *Annals* were lying there too. I have several articles on the stocks—but more of this anon.

Dr. Hope intends to give another lady's class this winter. I have heard him lecture once or twice, and set him down for a complete puppy.

Edinburgh, Dec. 20, 1826.

My Dear Mother,—Dr. Ritchie, the Professor of Divinity here, has been doing all he can to prevent Dr. Chalmers from succeeding him. With this purpose he continued to lecture till a few days ago, although he was not heard in the first bench. One day a gentleman, who passes under the name of Dr. Syntax, and attends

all the classes, came in. He was applauded upon his entrance, but considering this as meant to insult him, he made a long speech to the students during the lecture, which Dr. Ritchie is so deaf that he did not notice, so that the students were enlightened by two lectures at once. At the conclusion of the lecture Dr. Syntax stepped up to the professor and advised him in an audible voice to resign his situation, for no one heard a word that he said. Principal Baird has latterly been reading his lectures.

The Hunterian Society had an anniversary dinner at which several of the professors were present. I had been pitched upon to toast Professor Leslie, who was to be there, but was awfully cheated of my speech. For just as I was about to rise and deliver my most eloquent speech, Professor Leslie was obliged to leave the room upon business. Mortifying, indeed!

[During this year he was occupied with three papers—(1) "On Absorption of Gases by Liquids;" (2) "On the Heat of Friction;" (3) "Alcohol Derived from Fermentation of Bread."]

Edinburgh, June 29th, 1827.

My Dear Mother,—Johnston brought me a letter from Steel, and two letters of introduction from Dr. Thomson to Professor Leslie and to Dr. Turner, Lecturer on Chemistry here. Both of them I have delivered, and been very kindly received indeed.

I found Dr. Turner in his house, Pitt Street, New Town. He is a very gentlemanly young man, apparently not above thirty. He is chemical editor of Dr. Brewster's *Scientific Journal*, and has written a good deal on chemistry. We were conversing together for more than an hour. He showed me a work which he has very nearly finished, and which will be published in a very short time—"Elements of Chemistry"—in one thick volume. He intends to have a ladies' class for chemistry this winter in the Assembly Rooms, instead of Dr. Hope. During my stay his sisters came in, and were jesting about the method in which they had been carrying round the hand-bills about these lectures in their muffs, and leaving them at music shops, and wherever they called. Dr. Turner promised to return my call, and hoped that we would become well acquainted.

Professor Leslie resides in Queen Street, and there I found him sporting a dressing-gown. There was even a longer confab here than in the former case. He is a bachelor, and his drawing-room

has a good deal the appearance of a laboratory, so that there were plenty of instruments to show and discuss. As I suggested to him a variation and improvement in a favourite process of his, he was so good as to offer me the use of his instruments to perform it. He also requested me to prepare some chemical things for him, for I find that although an excellent mathematician and natural philosopher, he is no great chemist. He also invited me to step into his class and his laboratory whenever I chose, and to call at his house. He took my address. As Dr. Thomson's letters were sealed, I did not see what they contained, but I should think that they were very favourable, as the first question that both Professor Leslie and Dr. Turner asked was, if I was intending to give a course of lectures. I am much obliged to Dr. Thomson for these letters, as they give one an excellent introduction to the scientific society of Edinburgh.

Steel, in his letter, without any commands from me, had enclosed 15s. 6d., my share of the Chemical Society's funds. It came very opportunely, although I would rather that it had never come out of Glasgow.

Edinburgh, January 29, 1827.

My Dear Margaret,—The ginger-bread was excellent. Mr. Johnston got away the last of it as a supply for his Durham journey, thinking greatly of it from the scientific principles upon which it had been baked.

I was surprised the other day by the receipt of the card which I have enclosed for your profitable edification—from Chalmers the bookseller, the Doctor's brother. I have been led to understand that it arose from something which Mr. Dunn, the optician, had said to Mr. C., of and concerning your humble servant. Upon calling upon Mr. C. as requested, I found that he was in a great dilemma for material for the new popular journal of science which he is setting about, and the plan of which he borrowed from our Chem. Society, and that he wished me to give him some papers—offering six guineas a sheet of 24 pages, 12mo; the intended magazine being of small size, containing 60 pages for one shilling, to be published monthly. As I might publish anonymously in it, I told him that I would think of it.

By the Powers! a very good method of adding two or three guineas a month to one's income. What he wants is quite

different from what would go to the Annals, so that they do not interfere, and, as I wont put my name to them, the L. can know nothing about it. Although I have been otherwise very throng, I have sent him two or three short things, and will send him some more for the first No., which will not appear for near a month yet. I suppose he pays when the articles are printed.

Another great advantage of it is that, for the purposes of the Magazine, Chalmers receives all the scientific journals, British and Foreign, and submits them to his contributors. The obtaining a reading of them the moment they come out is what I would have given anything to compass.

Notwithstanding my denial, some of my friends maintain here that I am the Editor of the Magazine. Where they got the information I know not, as I never told them anything about it.

Hoping that you will be satisfied for a season with the above news, allow me to subscribe myself on this side of the sheet,

Your affectionate brother,

THO. GRAHAM.

Edinburgh, Feb. 23rd, 1827.

My Dear Mother,—I was surprised yesterday by a visit from J. Renwick, with parcel of provisions and packet of letters. He called when I was out looking after a situation for Mr. M. Miller. Mr. Miller is rather troublesome with his situations, and I am determined not to put myself to much trouble in regard to them; for, after having, with a good deal of manœuvering, secured this situation for him, he declined it. It was a private classical academy in Newcastle, like Johnston's, and which was either worth, or might easily be made worth £150, while he is canvasing away here for a Lancastrian school not worth £80, and not half so respectable.

The publication of *Chalmers' Miscellany* has been rather hindered for a few days from his absence, occasioned by the death of his mother, but it will be out by 1st March. During his absence Mrs. Chalmers had the charge of affairs, and I was prime minister. Mrs. C. very much regretted her mother-in-law. She was upwards of 90, and was perfectly sensible. Young Mrs. C. had a letter from her within six weeks of her death, with a present of stockings

for the children, of her own knitting. The doctor was her fourth child, and our Mr. Charles C. among the youngest. Her oldest son has been all along in London. The doctor left his class, and was with her at Anster, in Fifeshire, during her last illness, which was not severe, and only ten days. Mrs. C. said that she had a great care for all her sons' wives, and liked to bring them all together about her.

Mr. Renwick stayed here last night. I find upon looking at the box of instruments that they are in a very bad state. I have never opened them since I came here. Perhaps some of the deficient instruments may be lying about the house.

Edinburgh, Feb. 27th, 1827.

MY DEAR HENRY,—You will see that Chalmers' concern is printed. The woodcut on the title page was rather got up in a hurry, but it is meant for a head of Dr. Franklin. Some say that it is very like Chalmers himself, and that will probably be the prevalent theory among the knowing ones at Glasgow. It is rather thin, but he intends after he has printed a volume to add a sheet and half more to it, and charge 1s. 6d. My signature is G.

There is one of my suggestions which you will find under the head of "A Valuable Appendage to Kitchen Fire-places," which has wondrously caught the fancy of our *Ebony*. He says that it is calculated to produce a complete revolution in the sublime science of cookery—that all the blue-stocking ladies of Edinburgh to whom he has mentioned the improvement are captivated therewith, and that a thousand and one sand baths are forthwith to start into being. There must, he says, be another and a long article upon it in the next number, and Mrs. Chalmers has been so kind as to furnish me with Dr. Kitchener's "Cook's Oracle," in order that the article may be garnished with apt quotations and "modern instances." I shall probably devote a couple of hours to it some time this week.

These, however, are merely subordinate pursuits, and neither they nor their fruits are what I aim at. Eminence purely scientific is more philosophical, more honourable, and more desirable in my eyes. But leave it to time.

Edinburgh, March 15th, 1827.

MY DEAR MOTHER,—The other day I got £5 from Chalmers for contributions to his magazine. It was quite a Godsend. It certainly came very seasonably, as I do not expect a remittance from the L. for a fortnight, if at all. I have had no letter from him. I have great pleasure in sending the little presents which accompany this, as the first-fruits of Authorship. The expense of them, I can assure you, was a mere trifle. They would have been better, had it not been for the temptation of adding some conveniences to my laboratory. The ring which I request you to accept of, you will perceive is for hair. Just start out the glass front, by putting the point of a penknife into one of the ends; and the hair is put where the silk is at present. It is quite easily done, and there is no danger.

Do not make yourself uneasy about the L. sending money, for, if I was applying myself to it, Mr. Chalmers is quite willing to give me as much of the magazine to write, as would yield me five guineas a month, which is more than I get from the L.

Edinburgh, March 15th, 1827.

MY DEAR MARGARET,—I saw Prof. Leslie yesterday, and he says that his ladies' class has succeeded beyond expectation, and keeps him tremendously busy, and he introduced a good deal of chemistry for their amusement, in which he is by no means an adept.

I intend to have Dr. Turner at breakfast some of these days, and to introduce Bentress to him, as Dr. T. studied at Gottingen under the celebrated Stromeyer, and Mr. R. intends eventually to land there.

Edinburgh, April 16th, 1827.

MY DEAR MOTHER,—I have had a good deal of intercourse with Dr. B. [Brewster], chiefly, if I recollect, since my last letter to Henry by Mitchell's parcel; indeed, it was by a mere accident that Miss Cameron's lodgings escaped a visit from this doctor of encyclopedic renown. Bentress and I were promenading Princes Street upon some business or other, when we met with, and were hailed by, Dr. B. He was on his way with the tickets of admission

to Sir W. Hamilton's phrenological lecture for us. We had then a walk, arm-in-arm, the whole length of Princes Street, the doctor in the centre. Bentress had nothing to say, so that I had the whole conversation to keep up with the doctor; but he is a person with whom one feels perfectly at ease. He was anxious for a paper—proposing as an inducement fellowship admission to the Edinburgh Royal Society.

Talking of Dr. Brewster, I do not recollect whether I mentioned that he had sent me a present of some specimens of carbon, similar to what Colquhoun describes, and which Margaret will recollect. He also sent me a liquid to examine, obtained from a portable oil gaswork in London, which is rather curious. He mentioned that upon being poured upon hot water it took fire. For, one night, when drinking toddy with some others in Sir Walter Scott's, having accidentally had it in his pocket when the servant came in with more hot water, he poured some of the liquid upon the hot water, and it took fire. I suppose that they had all been rather groggy, for when I told him that I thought it impossible that it could have taken fire of itself, he confessed that perhaps some of them had set fire to it.

By the bye, the sand bath, although it cost me very little thought, is making some noise here. Mrs. Chalmers, of St. Andrews, and many ladies here, are getting them erected. Do you think I write popularly? Mr. Chalmers thinks as much of my new article on "A Marine Amulet" as he did of the sand bath.

Edinburgh, May 27th, 1827.

My Dear Mother,—I think that I will be home for certain within a week. Indeed, I would have come off with Mr. Mitchell had it not been that the whole of my pecuniary interest in this sublunary world amounts to three sixpences, so that it is necessary for me to remain a few days and write to raise the wind.

May 30th, 1827.

I look forward with great pleasure to my visit to Glasgow, as notwithstanding that I have now been a whole year in Edinburgh, I feel as much as ever all the solitude and desolateness of being in a land of strangers, which, from my retiring habits, will be always the case wherever I go.

Edinburgh, July 20th, 1827.

My Dear Mother,—I have seen Chalmers twice, although neither of the times did I enjoy a private *tête-a-tête*, as other people were present. He seemed, however, to say that the sale of his journal had latterly been considerably injured in England by the "Library of Useful Knowledge." It was detained last month in expectation of a plate from Dr. Fleming of Flisk, which, however, did not come forward. Wilson, the painter, and Browne, of the Hunterian, were up last night.

I have not yet returned to my labours, but am drawing up a plan for them. Everything is sufficiently encouraging, although I shall never know rest and peace till I get them completed. But perseverance, I doubt not, will overcome every difficulty.

Edinburgh, August 1, 1827.

My Dear Mother,—I have not seen Chalmers for near a fortnight, so that I do not know what his present plans are. I am busy at present with writing a treatise of a chemical nature on "Steam as a Moving Power," and performing some experiments which the subject gives rise to. It may be profitable in two ways—first, as a book, for it would make a small one, and there is at present a great demand for such a book, for all the previous writers of such books were engineers, and confined themselves to the machinery of the steam engine, neglecting the chemical properties of steam, upon which everything depends, and of which they are in general wofully ignorant. Secondly, my investigations into this subject have led to a slight improvement, which may be applied with the greatest ease to such engines, and increase the power of the steam by one-fourth, or more—but of this anon. I may add that I had been applying myself to this subject a considerable time before I was West with you.

Edinburgh, August 6th, 1827.

My Dear Margaret.—I had occasion to see Blackwood the other day with the business of *another* Miss M., although a less attractive and less lovely object. It was towards the end of last week. Chalmers had seen him that forenoon, informed him of my errand, and prepared him for my reception. Upon entering the

shop, I requested one of the young men to inform Mr. Blackwood that Mr. Graham waits for him. Ebony immediately made his appearance—a business bustling like man; said that Mr. C. had informed him of my business, and requested me to walk on with him. He led the way through a saloon, with a large circular table in the centre, piled with new works, magazines, newspapers, and other ambrosial sweets, around which there sat authors, blessed in their labours, happy spirits! Beyond, at the little door of a deep recess—a most holy sanctum—Ebony drew up in position second, and beckoned my entrance. It was a little cell, and the scanty light from above played upon the busts of Scott and Byron, supported on a marble table. These, with two chairs, constituted all the furniture of the den. It soon appeared in our conference that Ebony had determined to fight Shy. "So many excellent novels have now been published, that nothing except what is very superior would sell, &c." He enquired what was the nature of the story and if the authoress had ever published before, and he concluded by saying that if I sent it down, he would look over it, although he might not be able to say anything about it for a week or ten days. I sent him the manuscript that evening, so that it is now in the hands of the Philistines. I suspect much, from what little more I read of it before sending it away, that it will not suit Blackwood. The first volume is historical, well written, and interesting enough for a *first* volume. But in the second volume long conversations are given, which have certainly the merit of being true to life, but to me at least feel exceedingly dull and vapid. Instead of leaving the heroine Juliet's loveliness as much as possible to the conception of the reader, so that every one may mould her to their own standard of beauty, and none be shocked, she is described most needlessly at sixteen, as "tall and overgrown." Certain young ladies are introduced in "yellow bonnets fitting the head." Now such might have been the fashion at the period referred too, but the reader of the present age cannot help associating something ridiculous with characters so described. A bad impression is produced which tells against such characters, till the reader has forgot the circumstance. It was quite unnecessary to mention it.

I wish that I had seen the second volume before I left Glasgow, as it would have prevented me from being so sanguine of its success. I depended also upon Miss M., who told me that the latter volumes were *much better* than the first.

Edinburgh, 16th September, 1827.

MY DEAR MOTHER,—I was very anxious to hear from Clover-Bank till I received Margaret's letter yesterday morning. You see I send in another statement—as it is certainly the best policy to do so as often as possible—sufficiently imaginative like the rest. We are well here and exceedingly comfortable. The weather has been rather broken here for a week or two, so that the laboratory, with its little furnace, is the most comfortable room in the house. I have *scanned* off my allowance two very fine thermometers of great accuracy and beauty made by Dunn, and some other things, so that I now go on pretty smoothly.

Robert Logan of Eastwood has been here for a few days, he promised to call up immediately and to convey this parcel, so that I am, as usual, pressed for time. By way of ballast I send you a couple of letters, and the scrawl of one of mine. Johnston had sent up a paper, that I should deliver for him to the R. Society, upon which he had been working away for two years, for he has never published anything. I at once detected a serious oversight which pervades the whole of it, and will expose him to a severe basting if he publish it. I accordingly wrote him as you have it in the scrawl. His letter is an answer to mine—a good deal nettled, you will see, and talking nothing to the purpose. I have also answered that, and shown him to be wrong by experiment. The other letter is a curiosity, in so far as it has been in the penny post, and trying all the Grahams in Edinburgh since June. It is from Dr. Thomson's nephew, Steel. The whole address originally was "Mr. Thomas Graham," till at last it had fallen into the hands of some person who knew me and completed the address. The postman delivered it last night with that account.

Edinburgh, 1 W. Richmond Street, 4th October, 1827.

MY DEAR JOHNSTON,—Your paper I received last night, after it had been opened by a person of the same name who resides at 1 W. Nicholson Street. To-day (Thursday), with the intention of delivering it, I have called twice on Dr. Turner without finding him. Nevertheless, trusting to your friendly indulgence, I have at last concluded, after a severe struggle, to retain the paper and take no further step till I have communicated with you. I

employed the greater part of last night in perusing the paper; the result was the discovery (which the clear manner in which your results are stated made the more easy) of a most important oversight—not, however, in what you candidly allow to be the debateable part of the essay. You make Gmelin's salt, or your chloro-ferro-cyanide of potassium, to consist of

½	atom	chlorine.
3	,,	cyanogen.
1	,,	iron.
2	,,	potassium.

and of these elements (mark) *alone*, no water, no hydrogen, or oxygen present. Now this constitution is totally subverted in a passage which occurs in page 21 of your paper, and is as follows:—"Heated in a tube they (crystals of chloro-ferro-cyanide of potassium) give off no water. As the heat approaches to redness it is decomposed, giving off *hydrocyanic* acid and *ammonia*. At a bright red heat it blackens and melts, and is at last totally decomposed, leaving *potash and peroxide of iron*."

Here we have oxygen and hydrogen in abundance in a body which professedly contains not an atom of either. An analagous result of the igneous decomposition of the old ferro-cyanide of potassium did not disturb Porrett or Berzelius [and perhaps that misled you]; but why? Because they allowed 3 atoms water in their salt, the *decomposition* of which accounted for the disengaged oxygen and hydrogen which appeared. Now, unfortunately, your theory is expressly founded on the supposition that these 3 atoms of water are got rid of. The decomposition of your chloro-ferro-cyanide should have strongly resembled that of the cyanide of mercury; and a very important body it would have been, enabling us to procure potassium at once. I had been attempting in vain to form a true cyanide of potassium for that purpose. You must therefore either sacrifice your experiments on the composition of Gmelin's salt or your theory. I mean not here by your "theory" the particular theory of a chloro-ferro-cyanic acid, to which you give preference—but every theory according to which you can arrange the same elements, of which you give two if not three (pp. 12 and 13). To save your *experiments* you may deny the correctness of the common analysis of prussiate of potash thus yielding up your theory, as it is founded on that analysis. To save your *theory* on the other hand you must retract your experiment on the decomposition of the salt by heat. But the

fundamental synthesis of your salt given at the beginning of your paper applies strictly not to the ruby crystals obtained on solution, but to the "yellow substance" formed although the ruby crystals *are not* a chloro-ferro-cyanide of potassium or compound of such elements, the yellow substance might be, although I do not believe it. Expose this latter substance properly dried to a red heat, and see.

Repetition of your experiments would probably show that the whole three atoms water in the prussiate of potash are not displaced by the chlorine. It is there you should look for the error. At present your theory is contradictory.

As your character as an accurate experimenter might be injured by the publication of your paper in its present shape, although perhaps in no department of chemistry are such mistakes more allowable, I hope you will forgive the extraordinary procedure I have followed. I am afraid I have presumed too much. But still your paper is valuable—you have ascertained the existence of chlorine in Gmelin's salt, and from an individual salt you have raised the class. These results might be published without the synthesis which alone are defective. I fear that from your extreme susceptibility you will feel this partial failure more keenly than you should. Your paper might be remodelled, so as to be unexceptionable, although with diminished pretensions. Anxiously awaiting your commands.

I remain,

My Dear Johnston,

Your affectionate friend,

THOS. GRAHAM.

I strongly suspect (although at present I have not room for my reasons) that the common analysis of Prus. Pot. on which you found is inaccurate, and that it really contains *more* water and *less* cyanogen. Should this be the case, you may get out of the dilemma with your experiments safe—although not with your theory. I hope it may. T.G.

Durham, 7th Oct., 1827.

My Dear Graham,—I have this morning received yours dated the 4th. I don't know how it has been so long on the way. The fellow that got the packet must have kept it a long time. However, &c.

What a desperately acute fellow you are, and with what a vengeance you write. Your objection is certainly valid, but even were it sustained it would have no such overturning effect as you suppose. You will observe that I allow 3 atoms water to the salt of soda, and yet it contains the same acid and is a cyanide (if you like)—the water being that of crystallization. It is in this light that Berzelius views the ferro-cyanide. Nor does *hyd.* enter into the composition of the ferro-cyanide of Porrett—neither, therefore, need it enter into that of the chloro-ferro-cyanide—so that the whole question consists in *whether the salt of potash contains water or not.* It is true that I have founded my reasoning upon the constitution of that salt, but this was merely because it was the first formed—the most easily formed—and that to which my attention had been chiefly directed. Any other salt would have done as well, only if it contained water it might have been said that the *hyd.* of it formed a part of the acid. But that the chlorine at least of none of the salts, even of those containing water—that of Barytes, for instance—is not combined with *hyd.* is manifest by their giving off uncombined chlorine when treated with concentrated sulph. acid. When you mention the *yellow powder* as probably anhydrous, and as the only thing to which my remarks apply, you forget the experiment stated in which the salt dissolved and carefully crystallized gave exactly an equal weight of anhydrous crystals. I hope you see, then, that, allowing your objection, your conclusions are unsupported, for even if the salt of potash did contain water I had only to say with Berzelius—Yes, but it is water of crystallization. And then you will observe that I have stated the quantity of water in all the salts as very difficult to determine, and in no one case, so far as I can recollect, have I spoken upon it with absolute certainty.

Thus far, for argument's sake, have I discussed the theory of the matter with you. But still the salt of potash is *anhydrous.* The passage which has given rise to your speculations has apparently been carelessly written, whether or not I read it over again. I am not certain, but I am sorry that I have not a copy of it. I take it for granted, however, that the extract you have given me is a literal copy, and I have to beg of you to make one or two alterations to prevent any such mistakes in future. 1st. For peroxide of iron, read *carburet* of iron. 2nd. The second clause refers to the application of heat in contact with, and correct the whole as follows (I copy from your letter, and make as few altera-

tions as possible to save blotting):—Heated in a glass tube they give off no water. *In a platinum crucible*, as the heat approaches to redness, *the salt is partially* decomposed, giving off hydrocyanic acid and ammonia. At a bright red heat it blackens and melts, and is at last totally decomposed, leaving Potash and *carburet* of iron. Here the underlined parts are the corrections. The substitution of *peroxide* for carburet has, I suppose, arisen from thinking at the moment of the *green sediment*, which, when heated in an open crucible, gives peroxide of iron. Now, you will see at once the source of the hyd. Potassium, when heated in contact with air, burns and becomes potash; hydrogen therefore will be evolved in proportion to the quantity of the oxygen it obtains which is due to the decomposition of moisture. You say its decomposition if anhydrous should be analogous to that of cyanide of mercury; and so it is—heat cyanide of mercury in the open air—it blackens, melts, and gives off *white* fumes of hydrocyanate of ammonia. Whence comes the *hyd.*—is it from water in the cyanide? As to the absence of water in this salt, Gmelin and I agree; it is not, however, beyond dispute, but the contrary is unsupported evidence.

I copy the following experiment from my note-book. I wish it could be inserted in a note; it would show how difficult it is to decompose the salt entirely, and that the iron is in the metallic state:—"5 grns. heated to redness in a platinum crucible over a spirit lamp first decrepitated, giving off hydrocyanic acid; ammonia was then evolved in considerable quantity, and this continuing, the crucible was covered and exposed to a strong red heat. Removed from the fire, a *greyish black* powder remains, which appeared to have been in fusion. With dilute muriatic acid it effervesces strongly, giving off the smell of hydrocyanic acid. The solution obtained gave a precipitate of iron with benzoate of ammonia, the previous filtration having left a slight blue sediment on the filter. There remained undissolved a shining black matter at the bottom of the crucible, which, by repeated digestion with nitric and muriatic acid, was partially decomposed, and in solution gave the precipitate characteristic of iron. It was, therefore, carburet of iron, and the metal taken up by the dilute muriatic acid was probably in the state of carbonate. The blue sediment shows a portion to have been still undecomposed."

This experiment is dated 18th December, 1826, and was made in Thomson's laboratory. If you think it is of any service, I will

be obliged by your writing it on a bit of paper and introducing it as a note to the word *Carburet.*

If I have not succeeded in satisfying you, I have so in assuring myself that you have been hasty in supposing this *lapsus* to overturn all my reasoning. As to repeating the experiments you mention, I am satisfied myself upon the point. I have made hosts of experiments—many of which are not stated in the paper. Any more made are from blunders of the kind now corrected. I have stated nothing which I have not verified or considered as already settled. I conceive that upon reconsideration you will find reason to be satisfied with the presently received composition of the prussiate of potash. It is very difficult to determine the water certainly, but I cannot see how you can increase it at the expense of the cyanogen without also altering the amount of bases. I have tried to estimate it, but certainly could not depend on my own results if different from those of Thomson, Berzelius, and Philips. I rely on Dr. Thomson the more as he has stated that he had been obliged to come to that conclusion though anxious to obtain a different result.

In my last letter I did injustice to Mr. Faraday in relation to the disinfecting liquor. I have since had occasion to alter my opinion in regard to his correctness, and I, therefore, hasten to make him amends by saying I believe him to be right.

I had the pleasure of seeing a handsome notice of your paper on *solution* in the *Quarterly Journal* for this month. Unfortunately I have no opportuuity of seeing the *Annals*, and, therefore, I got there the first notice of the publication of your paper. What is given in the *Quarterly* (Brande's) I agree with perfectly. There is only about a page: I should like to see the whole paper.

I hope that after making the corrections stated you will give in the paper as early as possible. I fear it will now be too late to have any chance of insertion in the *Transactions.*

Be kind enough to give me as early intelligence as possible, and believe me, my dear Graham,

Yours very sincerely,
(Signed) JAMES F. W. JOHNSTON.

Edinburgh, 12th Nov., 1827.

My Dear Mother,—I have been exceedingly negligent in my Cloverbank correspondence, notwithstanding the highly exemplary

conduct of my correspondents. I can scarcely hope to be excused, but the truth is that I was never so busily engaged as during the last five or six weeks (anxiously engaged, too). Dr. Brewster, who manages the Royal Society here, is out of town, and intends to be so during the winter. In the course of a few weeks the Society intends to publish a volume of transactions in which I am very anxious to have two papers. One of these papers is already in the hands of Dr. Turner, and is highly approved of by him and John Robinson, being, according to the doctor (modesty avaunt!), "a beautiful and complete thing." The other paper is just finishing, and is a horribly long one, containing an account of 40 or 50 new compounds, and such is the burdensome richness of the mine I have opened, that I could easily add as many more. Dr. Turner, whom I have told of the nature of the discoveries, says that it will form a capital paper also. There is, therefore, no difficulty whatever in getting the papers read, and eventually printed by the Royal Society, but the point is to get them read at the very first meeting of the Society, otherwise they will be too late to appear in the forthcoming volume of their transactions, and perhaps would not be printed for a year. Now, so little confidence have Turner and Robinson in themselves that, protesting they will do everything in their power to meet my wishes, they are not sure whether they will be able to have both the papers read the first night, in fact they are quite confused without Dr. Brewster to direct them, and there is really no difficulty in the case. If they do not pick up courage, I will write to Dr. Brewster, who will dissipate all their imaginary difficulties in a moment. If they cannot be got read and printed immediately by the Society here, I will take the advice Leslie gave me the other day, and send them to the Royal Society of London.

Notwithstanding my hurry, I can assure you I have been in excellent spirits, and as for health, strong as a thousand elephants. Miss C. is also well, and everything comfortable. Never were things in a more favourable state should I choose to set up in a chemical line here, than they will be this winter or spring. Of the two lecturers, Dr. Fyfe is setting out to travel on the continent for his health, and Dr. Turner expects every day to be appointed to the Chemical Chair in the University of London. Should he go, I can depend upon getting his fine new laboratory moderately, with his practical classes, without any competition, in the absence of Fyfe. Dr. Turner is exceedingly confident that he

will get the London chair. He told me that the candidates beside himself are Dr. Fyfe, Dr. Ure, of Glasgow, and Mr. Phillips, the editor of the *Annals*—none of them great hands, although Phillips is certainly the most deserving. Turner thinks, however, that Phillips will have no chance, because he has never lectured, as if there was any mystery in lecturing. I think, however, that Turner has a very fair chance, particularly from his acquaintance with Leonard Horner, now the Warden or Principal of the University, who is an Edinburgh man. It is curious how little distinguished any of the candidates are; and, indeed, the circumstance that the election has been put off so long is not complimentary to them. Indeed, perhaps in no other department of literature or science is there so little competition in this country at the present day as in chemistry. The chief reason of this is that the most of chemists are medical men; their reputation soon procures them great practice, which is too tempting to be rejected, and chemistry becomes neglected amidst their extensive and highly-profitable professional engagements. This has been the case with almost all the great London chemists who should have been competitors for the chair, such as Dr. Prout, Dr. Wollaston, Dr. Bostock, &c. In fact, they were no longer chemists. Turner expects to hear of the issue of the election every day, as it was to be decided in the beginning of November. I confess I would feel rather reluctant at setting up as chemist in Edinburgh, preferring London, but all will depend upon circumstances. Meanwhile everything is encouraging. Should Dr. Turner succeed in getting to London, I will have a friend at court, and there is another chemical professorship—
On the Application of Chemistry to the Arts"—which probably will not be filled up for a year or two. In all these competitions everything depends upon sheer impudence, of which I confess I have too little, confining it to my letters entirely. When Turner first told me of his being a candidate, and of his confident expectation, it was only his presence that prevented me from laughing, for he rests his whole merit upon his having lectured for a few years, and having compiled "Elements of Chemistry," while his original discoveries amount to nothing, or are exceedingly trivial. Bentress would never give Turner any credit, and even told Dr. Brewster that he thought he rated Turner too highly. But Dr. Turner is very courteous, and really an amiable character, so that people are charitable in their opinion of his talents; and, for my part, I will be happy in his success. You recollect of Johnston's

faulty paper, as he insisted I was obliged to give it to Turner, but at the same time told him that I did not warrant its accuracy. I was somewhat amused at Turner and his paper afterwards. He had examined it, and saw there must be something wrong in it; but being like Johnston, not overly clear-headed, he could not see precisely where the error lay. The next time I met him I soon found he was fishing me to find where I placed the error. Of course this must have been disagreeable to him, so I spontaneously explained the whole matter. It was then "as clear as day, an error that overturned the whole theory," &c., and I was requested to intimate to Johnston that, while his paper contained so palpable and manifest an inconsistency, it would not be recommended to the Society. This I did as mildly as possible, for I am really sorry for poor Johnston. Johnston, however, has given me provocation which, from any other person, would have been unpardonable—in a second letter some time ago—but he has now virtually surrendered, and must feel the excess of regret for his nonsense. I have scarcely room to subscribe myself

Your affectionate Son,

THOMAS GRAHAM.

Edinburgh, 19th Nov., 1827.

My Dear Mother,—Dr. Turner has been appointed to the London University, and I am to succeed him here, so far as succession is practicable. I am to take up his experimental or laboratory classes in three months hence, or in February, and to commence a summer course of lectures of three months in May. During that time I am to have the free use of his laboratory, apparatus, and everything, which is an unspeakable advantage. But next winter I shall be obliged to get a class-room, &c., of my own, as Dr. T.'s devolves by an old compact on Dr. Cullen, the lecturer on the Practice of Physic. But other favourable circumstances may arise before that time, and at any rate the present advantage is not to be rejected, while the accident of appearing as successor to the Professor of Chemistry in the University of London is itself of some value.

These experimental classes to which I refer consist of half a dozen students and upwards who come to the laboratory for an

hour, and get half lecture, half experiment, assisting in performing the experiments. The fee is three guineas a quarter; and one may have more than a single class of this kind in a day. They are what you would call private classes.

Dr. T. is going up to see how things are doing in London at Christmas, and it is probable if his stay is protracted that I may lecture for him at that time, for a few days, both in his own public lectures and in the School of Arts, where he is at present lecturing in the place of Dr. Fyfe.

He has promised, while at London, to recommend me as a fit person for writing certain Treatises on the Chemical Arts "in the Library of Useful Knowledge" to Leonard Horner and Mr. Brougham.

He informs me that it is agreed that Dr. Hugh Colquhoun and I are to be proposed as members of the Royal Society at an early meeting. . . . . .

[During 1827 Graham was occupied with three papers—(1) "On the Finite Extent of the Atmosphere;" (2) "Longchamp's Theory of Nitrification;" (3) "On Exceptions to the Law that Salts are more Soluble in Hot than in Cold Water."]

Edinburgh, 11th Jan., 1828.

My Dear Mother,—Dr. Turner resumed the class yesterday. He was up here, but for so short a time that I got scarcely any news from him. Sir H. Davy had a paralytic stroke, but is getting better. Mr. Phillips, the editor of the *Annals*, has left London, having got the superintendence of some great work about Birmingham. Dr. T. was highly pleased with his reception among the dons. He breakfasted last Sunday with Mr. Brougham. The arrangements about the class and laboratory are quite agreeable to him. The class-room holds 500 seated. He must go up sooner than he expected—in July—and open his class in Oct. In the lecturing I was more at my ease this week. One night I was upon phosphorus, had the room darkened, and was exceedingly flashy. I was much amused by the fellows becoming rather uproarious in the dark, just as we used to be in the Pig's. James says that there was always a number of strangers present. I was slightly annoyed with two things—a touch of sore throat,

which I got from drinking a glass of water after finishing, and by inhaling a little of chlorine gas when making it, owing to James's fault in remaining away too long one day—I had permitted him to be operator to Mr. Ritchie, of Tain, who delivered a lecture on Oil and Coal-gas in the Assembly Rooms.

Edinburgh, Feb. 21, 1828.

My Dear Mother,—My silence has been so long as to be quite inexcusable, but I have been always deferring and deferring until I had something definite to tell you. Shortly after I wrote last I had two offers, both of which deserved attention. The first was through a Dr. Gardiner, from Constable Junior, to write a volume of his Miscellany (which you have perhaps seen) upon Heat and Electricity. This I was very much inclined to do, as I would be obliged to write lectures on the first of these subjects at anyrate. But I have long had it in view to translate and get published in a compressed form, like Ure's Dictionary, Thenard's French System of Chemistry, which in the original is in five volumes. I had employed Mr. Chalmers to sound some of the booksellers, and Oliver & Boyd embraced the proposal at once, and, after I was introduced to them, and had several meetings, offered to give me half the profits of the publication, without any of the risk, if I would undertake it. This would be considered a good offer as such things go, but at the advice of both Turner and Chalmers, particularly of Turner, I preferred another plan, for by the former one is quite in the power of the booksellers, who can estimate the profits at what they choose. This is just to require a certain percentage on the retail price of the book, say 10 or 12 per cent. upon the price of every copy printed, which would probably be sold about 25s. Oliver & Boyd have not expressed an opinion as yet upon this plan, and the whole arrangement is postponed till a copy of the last edition of the original (lately out) can be procured from London, and I believe it will not arrive before the commencement of next month.

It would take about a year to translate Thenard and write notes to it, and the profits of the first edition might be about £120; but then there would be as much on every subsequent edition. It would also be a great thing to have one's name attached to a book

of such weight and importance. Turner thinks that if he were in my situation he would adopt the plan at once. Dr. Thomson first brought himself into notice by translating Fourcray's System of Chemistry. In the meantime, however, I have been doing something to Constable's business, as it would require more than two or three months—the return about £30—and as the materials will do for lectures. On all these accounts I have deferred the experimental course, of which the success would be rather problematical, but am still ready for the lectures, should things yet turn that way. But I am somewhat unwilling to set up as a regular lecturer in Edinburgh! It is so medical. . . . . .

Edinburgh, 8th April, 1828.

MY DEAR MOTHER,— . . . . . . I was admitted into the Royal Society last night. I don't care although the L. should know, but should he think that there is anything to pay it will take away all the merit of it.

Friday, April 25, 1828.

MY DEAR MOTHER,— . . . . The business with Boyd, of Oliver & Boyd, is not yet settled, although I have delayed from day to day to write you, expecting that it would be settled. He seems determined to make a good bargain, and to-day I received a note from the firm, declining my proposal of £130 sure for the first edition, and half the profits on every subsequent edition, which might be estimated at £100 on each subsequent edition. It is not my charge for the first edition which he quarrels with, but he seems to think that if I am made sure of so much on the first edition that I have no title to so much as half the profits upon subsequent editions. I am quite aware that my proposal as to subsequent editions is high, but Boyd is so wary that it is difficult to guess what proposal as to that matter he would be disposed to fall in with. He won't suggest anything. . . . . . . At the Royal Society last Monday I had a paper, and made my *debut* as a member. Johnston, of Durham, was rejected in the Council as a

member, where he was proposed by Dr. Turner, at his own urgent request. I had a great deal of talk with Dr. Hope as to Johnston's merits, and kept him up as well as I could, but to no purpose. It was Dr. Hope who occasioned his rejection in the Council, he being, as Miss Cameron says, "no poor man's friend." . . . . Hope told me that he had repeated my alcohol process, "which he fancied," before his class with success—it takes a week, so that it is no bad advertisement—and added, with a pomposity which was almost too much for my gravity, "and may I be allowed to ask, Sir, was this beautiful discovery the result of accident or of research?" Humbug.

[Graham was occupied with three papers in 1828, viz.:—(1) "Experiments on the Absorption of Vapours by Liquids;" (2) "On the Influence of Air in determining the Crystallization of Saline Solution;" (3) "A Short Account of Experimental Researches on the Diffusion of Gases."

The poverty of Graham at this period is illustrated by the following curious anecdote communicated by his sister, Mrs. Reid:—"I dare say you know of his taking a very poor little "room at Portobello, and laying wires in the sea, mostly after it "was dark, but moonlight perhaps, for his experiments. His "landlady found some of his things below the bed in his room, and "told him she did not like to see such things, she doubted he was "after no good, and he had better take his leave. She put his "wires, etc., out at the door and bid him walk, she would rather "want a week's rent than let him in again; so poor Tom had to "hide his things and walk back to Edinburgh that night. The "rent of the room was 3s. per week, without fire, which was a "great deal more than he could spare at that time." Graham then returned to Glasgow, where he taught Mathematics for some time at the suggestion and under the patronage of the late Dr. Meikleham, Professor of Natural Philosophy in the University of Glasgow. Subsequently he had a Chemical Laboratory in Portland Street, where he also delivered lectures, and for the year 1829-30 did similar work in the Mechanics' Institution. In 1830 he was appointed Professor of Chemistry in the Andersonian University.

During the next six years Graham worked hard in Glasgow—lecturing, teaching, and sending out workers from the Andersonian University.]

Glasgow, August 2, 1831.

My Dear Margaret,—I had occasion yesterday to address, for the first time, that most learned body—the Faculty, for the purpose to get attendance on a course of Practical Chemistry made imperative, which should long ago have been the case. Mr. Harry Rainy seconded my motion, and our proposal was graciously received, although, as all dignified bodies move slowly, the bill must be read a second and a third time at successive meetings before it is passed into a law.

I do not know what to say for news. Some mad doctor at Port-Glasgow, it appears, lately alarmed the Government on the fancied appearance of the Russian cholera in that quarter, and occasioned a meeting of the Privy Council and other unnecessary measures. The Faculty replied yesterday to a letter of inquiry from Mr. Dixon, that the town was never more healthy at this season of the year than at the present moment.

Mülhausen, Alsace (Hotel de la Couronne),
1st September, 1836.

My Dear Margaret,—In his laboratory (Daniel Köchlin) we found the excellent chemist Schlomberger, he is an *elève* of Mr. Köchlin's, and who has written the best papers on Madder. The chemist was throng at work in his blouse-coat and wooden clogs. Köchlin is himself a most interesting person. By the way, C. Thomson is studying with him, and he has a high opinion of Walter Crum, and pronounces him, now that James Thomson is getting old, the most accomplished printer we have in England. The afternoon we devoted to Mr. Hoffer's own establishment; John finds them exceedingly communicative, and they seem to show us everything without reserve. He thinks that he has already attained the most important objects of his mission, and that he will be able, on returning, to produce the beautiful Madder rose-reds for which Alsace is famed, so that the journey will not be lost . . . . .

I was amused by the feeling which seems to prevail here in regard to the French Institute. They have never published Schlomberger's valuable papers on Madder, because they impugn the results of a brother member, M. Robiquet; although Mr. Köchlin spoke on the subject to Gay-Lussac, Chevreul, and others.

The fact, I believe, is that this exclusive dealing results from no bad feeling, but the Institute is a coterie, all the members are familiar with each other, and unwilling to give each other cause of offence. Gay-Lussac likewise, who is chemical editor of the *Annales de Chimie*, is an exceedingly mild man, and is certainly carried too far by the fear of offending his brother academicians. There is one of my papers which he has promised to publish (on Phosphuretted hydrogen), but which I would not be surprised to find him restrained from doing when he finds that I give more credit to Henry Rose than will be agreeable to M. Dumas. Dumas surprised me much the first day I met him by a hasty and unfair criticism on Rose, whom I defended. But afterwards, on reflection, he was at pains to undo the impression which his remarks might have produced, and finally transmits through me sentiments of respect to Rose, so that I hope to be the means of reconciling them.

Hotel de Rome, Dresden, September 27, 1836.

MY DEAR JOHN,—I have this morning arrived here, having travelled from Jena by way of Leipsic in company with Dr. Daubeny, of Oxford. After you left me at Frankfort I went down to Giessen and spent two days with Liebig. He is a most delightful fellow, and I was glad to find him in very fair health. Returned to Frankfort, and took the diligence to Weimar, near Jena, which I reached this day week. Between 300 and 400 "*Naturforscher*" had arrived, and the business of the meeting had fairly commenced. The arrangements were satisfactory, although there was not the same ostentation and amount of treating as at the British meetings. In the mornings sectional meetings—the Chemical and Physical Sections meeting together; a general meeting from 11 to 1, at which memoirs, or rather essays, of general interest were read. Dinner from 2 till 4, and sectional meetings again at ½ past 4 to 6 for those who had not taken too much champagne; and the evenings concluded very rationally with a ball at which there was a good turn-out of Jena beauties. As for the communications, they were interesting enough, but nothing strikingly important. Of the savans who had assembled Humboldt was the great star, but to me Mitscherlich was the most interesting.

I had a good deal of Mitscherlich's society, and found him very communicative. He has a most insinuating address, but there is a cold propriety in everything he says and does. I was sorry also to notice (and I made the same observation of M. Dumas) that when I stated any little discovery of my own he was fretted and could not conceal a little disappointment *because it had escaped him.* This was not like the hearty good feeling of Liebig or Henry Rose. But I have no reason to complain of Mitscherlich. My opinion of him as a chemical philosopher, high as it was before, has been elevated by my intercourse with him. I was particularly struck by the beautiful simplicity of some hints which he diffidently threw out as to the effect of a base, such as water or potash, on the corpuscular arrangement of particles which cannot subsist without a base. The base, which may be water, has here manifestly an effect upon the atomic constitution of the acid, if we could figure it to ourselves. Water may have a similar effect on the metaphosphate of water, which contains one atom water. The influence of the water on the arrangement of the particles composing phosphoric acid may be *different* from what it was in the other case. This idea of Mitscherlich is, of course, altogether hypothetic, and he by no means pressed it, but it is certainly a *very little* assumption, and we can observe in it the great secret of correct philosophising, namely, to advance by the shortest possible steps. In these corpuscular speculations it was interesting to observe how naturally he fell into the simple but philosophic views of Dalton in regard to atomic arrangements.

You know Clark's letter to Mitscherlich on a difficulty in isomorphism, which is unquestionably a most profound speculation. Mitscherlich has never noticed it, which in courtesy he was bound to do, even although he has had a second letter from Dr. Clark. I more than once started the subject, but he talked of having been so busy overhauling the arrangements of his laboratory, of being "tormented from morning till night," I suppose to palliate his neglect; and the speculation was evidently not to his mind—too striding for him. He alluded to other cases of similarity or identity of form besides that on which Clark founds, such as that of sulphur and bisulphate of potash, where the constitution of the two bodies is totally different. Mitscherlich's law is that two bodies which have the same constitution should have the same crystalline form, but it does not necessarily follow that bodies which possess the same crystalline form should likewise have the

same constitution. Mitscherlich disposed of the question by observing that because two and two make four that is no reason why three and one may not make four also. . . . .

Berlin (Hotel de Brandenbourg), October 10, 1836.

My Dear Margaret— . . . . This morning Magnus and I visited Prof. Enke by appointment at the Royal Observatory, where we spent several hours. The Professor explained all the admirable arrangements of a working observatory to us in detail. We saw the spots on the sun, and also the two stars which compose the double star Alpha Herculis, although it is only of the third or fourth magnitude, which, considering that it was bright daylight, was a very severe trial of his splendid Frauenhofer. I have not seen anything for a long time that pleased me so much as this far-famed observatory. . . . .

[About this time Graham sought the appointment of Professor at the University College, London, having during the preceding seven years been at work on the following papers, viz.:—(1) "Observations on the Oxidation of Phosphorus;" (2) "Notice of the singular Inflation of a Bladder;" (3) "On the Application of Spongy Platinum to Eudiometry;" (4) "Effect of Animal Charcoal on Solutions;" (5) "An Account of the Formation of Alcohol;" (6) "Researches on Arseniates, Phosphates, &c.;" (7) "On Hydrated Salts;" (8) "On Phosphuretted Hydrogen;" (9) "On Water as a Constituent of Salts."]

Sablonieris Hotel, Leicester Square,
London, Saturday, April 29, 1837.

My Dear James,—By the letter which I wrote (to Margt.) on Tuesday you would learn that I had started fairly in my canvass. I have seen nothing since contradictory to my first impressions. In whatever way it goes, the appointment will be made by the medical professors, who will take care to be unanimous, or nearly so. Of the nine or ten virtual electors I have good reason for believing that four, at least, are not only favourable but *anxious* for my appointment, while the others, so far as I can discover, are not as

yet committed to any other candidate. It is also a little fortunate for me that my supporters belong to both of the two parties into which the professors occasionally separate, although there is no serious division among them. But, as the whole force of the recommendation to be made to the Council by the professors depends upon their unanimity, I am not to expect that my four friends are to stand out in my favour if there should be a majority in favour of another candidate. It would be perilling their influence with the Council, without securing my return.

Johnston of Durham turns out, after all, to be my most formidable opponent. Both Mr. Richard Phillips and Dr. D. B. Reid would have some support in the Council—particularly the former, from his true respectability of character—but they are both given up for different, although sufficient reasons, by the professors.

Dr. Apjohn, of Dublin, from whom I feared most, has been rather inactive, and I think his chance of success inferior to Johnston's or my own, although he follows us.

I remain, DEAR JAMES,

Yours most faithfully,

(Signed) THO. GRAHAM.

Leicester Square, London, May 6, 1837.

DEAR WILLIAM,—At this moment I am in considerable doubt as to my movements. I had intended to start by the steamer for Leith to-night, and may very likely do so still, but the applications, &c., of the candidates having been lodged yesterday, and a meeting of the Council taking place to-day at 4, after the distribution of the prizes in University College, I am advised by Dr. Carsewell not to decide till I hear whether the Council takes up the applications at that meeting and refers them to the Senate, in which case a meeting of the professors would be called for Tuesday or Wednesday, and a committee then appointed to report upon the applications. Dr. C. thinks it might be worth while postponing my departure for a week to give that committee an opportunity of communicating with me personally if they desire it. The Council will sit till six, and I can scarcely hear the result before seven, which will be too late for the post at this distance.

I shall, however, retain this letter till the last moment. In case I remain here, would you make a point of seeing Mr. Young and request him to begin the Practical Course, and get on with it till the end of the week, assuring the students of my return at the beginning of the week following. . . . . . .

I remain, MY DEAR WILLIAM,
Yours affectionately,
(Signed) THO. GRAHAM.

William Graham, Esq.

In 1837 Graham was elected Professor of Chemistry, University College, London, and had his residence near it in Torrington Square, which he afterwards left for a few doors distant, at 4 Gordon Square, where he ended his life on the 16th of September, 1869. He held the chair of chemistry in the University of London for eighteen years.

London, Saturday, Oct. 21st, 1837.

MY DEAR MARGARET,—I have to-day completed the third week of my course, and am as well and comfortable as at the beginning of it. My number to-day is 221, which I have no doubt is the largest class on chemistry in the United Kingdom. I have got 70 pages of my first number in type, it requires 93 or 96. It is likely to be ready in time so far as I myself am concerned, but there is a risk of the woodcuts, about 30 in number, not being all ready, as this is the busy season for the annuals, and so forth. It is not a matter of much consequence, however, if it appears in the first week of November, as to the exact day.

We are all doing well at University College this season. I am very much pleased with the attention and respectful behaviour of my students, more than 120 of them have put down their names for examination.

London, Oct. 26th, 1837.

MY DEAR MARGARET,—At Sharpey's advice I have thrown away the papers, and for a few days past have been extemporizing. I am satisfied that it is the true system, and will come to be much

the easiest in the end. After I get my first No. out (which by the way is all in types), I shall not allow it to interfere with my other engagements, but only take it up when perfectly convenient. The extemporizing requires one to be both in good health and in good spirits, and I am determined not to risk myself for any consideration ; so keep yourself easy.

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36 Keppel St., Russell Sq.,
Nov. 3, 1837.

My Dear Margaret,—Already five weeks over. My No. in the class is 232, and a third student has joined the laboratory, a Mr. Fenton, of Rochdale.

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36 Keppel St., Russell Square,
Nov. 24, 1837.

My Dear Margaret,—I have after all left myself very little time to write to you. I had a very long and agreeable letter from Liebig a few days ago, conveying the information that his University have made me a Dr. of Philosophy *causa honoris*, but this is a profound secret, and to be kept like *all* such, as I am doubtful whether I shall make any immediate use of it, although it is very flattering. He has been reconciled to Dumas at Paris, and has a grand project of publishing a chemical journal in three languages, to be edited by Liebig, Dumas, and myself, but not before summer.

London, Dec. 2, 1837.

My Dear Margaret,— . . . My present number is 238, and we cannot look for any addition till January, when we may be joined by few new perpetuals, for we do not give the second term by itself. But you must not think that all my 238 are payees. This arises from the system of perpetual tickets.

Somerset House, 24th March, 1838.

Sir,—I am directed by his Royal Highness, the ——, President of the Royal Society, to communicate His Royal Highness's thanks

to you for having exhibited your very interesting experiment of the solidification of carbonic acid gas at Kensington Palace, and also to express to you the very great gratification which that exhibition afforded to His Royal Highness's visitors. I am further directed to suggest to you whether you might not present to the Royal Society an account of the experiment, which would be very acceptable to this body.

In thus conveying to you the sentiments of His Royal Highness, allow me to express to you my individual gratification in witnessing your truly scientific experiment on that occasion. I felt, I assure you, at a loss which most to admire—the highly important result, the philosophical beauty of the principles on which it was obtained, or its immediate scientific application.

I have the honour to be,

SIR,

Your most obedient Servant,

(Signed) S. HUNTER CHRISTIE.

Professor Graham, F.R.S.,
&c., &c., &c.

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9 Torrington Sq., Monday, March 11, 1839.

MY DEAR MARGARET,— . . . . I attended last night the first of the Marquis of Northampton's *soirées.* He has one of the large houses in Piccadilly, facing the Green-park, beyond Park Lane. There was a great turn-out. The heliographic drawings of Niepce, Daguerre's old partner (referred to in the *Athenæum* of this week), were on the table. They are on metal—extremely delicate and beautiful when seen in a proper light, suggesting a mezzotinto drawing. My idea is that the metallic plate, wetted with nitrate of silver, has been placed in a small camera obscura *containing hydrogen gas*, and then the prospect reflected in upon it. Where the light fell the white silver was deposited in the metallic state on the plate, and makes the lights on a darker metallic ground, while the shade can be etched afterwards by an acid from which the lights will be protected by the silver. But we shall see. Mr. Talbot's plan for prepared paper, in which the lights and shades are reversed, is curious but not at all new.

9 Torrington Sq., Monday, April 29, 1839.

MY DEAR MARGARET,—My compliments to Mr. Reid, and tell him that he may have the cabinet for £7 10s., neither less nor more (the sum for which Howard procured me the bookcase I have here), but not before his house is built and he finds that he has room for it. If not a very handsome, I believe it is a substantial piece of carpentery, as Mr. Young [Dr. James Young] used to pride himself on it, particularly on the hinges of the lower compartments, which are of his own invention.

[During the years 1837-9 Graham was busy with three elaborate and important papers, viz.:—(1) "On the Constitution of Salts;" (2) "On the Law of the Diffusion of Gases;" (3) "On the Theory of the Voltaic Circle."]

From York, Sept. 29, 1844.

To MRS. J. REID,—I write you in the middle of our meeting here, which has proved an excellent one. We have the best men in all departments and a pretty numerous attendance besides. My own Section is particularly favoured as we have the two stars of the meeting, Professor Matteucci from Italy, and Liebig. The latter has attracted crowds of country gentlemen to the Section, which is quite a new feature in it. Liebig is residing with the Archbishop, whose son, the Rev. W. Vernon Harcourt, is highly chemical. I drove out with Mr. Harcourt to dinner on Thursday at his father's, and arriving early had half-an-hour of the Bishop's company while the rest were dressing. He is a hale old man of eighty four, of strong sense and highly popular. He was using a stick from a lameness occasioned by his breaking one of the branches of the tendon achilles of the heel at the late Royal christening, of which accident he gave me a familiar account. He suffered so much that he could not have read the service, but having been a parish Priest before he was a Bishop he knew it by heart; and the Queen and Albert were afraid all the time that he would let the child fall out of his arms. His daughter Miss H. does the honours; and the young ladies of the family (her nieces) are fine girls, young Miss H. in particular, who has had a week of desperate flirtation with Rev. Deans and Professors who flock about the palace.

I return to London on Wednesday evening and will therefore miss the Liebig dinner at Glasgow.

Oct. 29, 1844.

To JOHN GRAHAM, ESQ.—I have had a bustling week owing to Liebig's return to London, and second visit. He saw no company except private friends, and did not visit out last week (except once) till we left for Oxford together on Friday after my lecture. This was a long promised visit for me to Dr. Daubeny, and I remained there till Monday, occupying Felton's chambers in the Dr.'s college (Magdalen) for three nights. This being term time, I saw Oxford, as you may suppose, to great advantage. The Doctor had his sister and two nieces on a visit to him in his official residence in the Botanic Garden, one of the said nieces is not quite a beauty, but everything else, and very dangerous.

Liebig returned before me on Saturday evening, accompanied by Dr. Buckland, who consented to remain with him at No. 9, and did the honours of the house till the return of the usual occupant. I wish Margaret had been here to have met the Doctor, his good nature and humour or rather classical drollery are quite overpowering.

Liebig had a very satisfactory interview with Sir Robert [Peel] after church on Sunday—Buckland introducing. Among other things, the Professor was asked his opinion of the new (proposed) College of Chemistry. He said that its character and success would depend entirely upon the chemist who should undertake its management, and that not being settled he could not give any opinion, although he thought favourably of the principle. It is, Liebig really believes, at present a job of certain parties, but I would not be surprised to see it taken out of their hands. Sir Robert enquired why not attach it to one of the existing institutions—University College or King's College. This Liebig thought the proper plan.

Dr. Buckland has much of the premier's confidence, and is, I can easily see, his principal scientific adviser. I have no wish to be encumbered with the new college, and believe that the means of teaching chemical analyses in London are sufficiently ample and cheap, more than the public will take advantage of. The best *locale* for a Giessen school is not London, but some country town, and it might be well connected with an agricultural college. I have no wish to meddle with such a speculation or be any way responsible for it; foreseeing, as I do, great perils and chances of

failure. Dr. Buckland, however, having extracted my views of the subject, adopts them, and I have no doubt they will go further. Sir R., I should mention, had expressed his willingness to go as far as to accommodate such a college of chemistry with house-room, provided the necessary expenses were otherwise guaranteed.

Dr. Daubeny was taken by surprise by the announcement in the *Standard* of Saturday that Dr. Dalton had left £4000 to found a new professorship of chemistry in Oxford (!!!) One of the executors (Mr. Nield, I believe) also informed Dr. Daubeny at York that he had a legacy of £100, but of neither of these circumstances has he received any official notice or confirmation. I wish you would let me have what you know on this matter. The will, having been sworn in Doctors' Commons, is, I suppose, published. Also, how your own proposed professorship in Manchester is likely to be received. Say how much I should subscribe. Dr. Daubeny proposes to give ten guineas, but perhaps you would expect twenty from one who fraternizes with the League, and has so much to interest him in Manchester.

[Between the years 1839 and 1844 Graham was busy with three papers, viz.:—(1) "On Preparation of Chlorate of Potash;" (2) "On the Constitution of the Sulphates;" (3) "On the Heat Disengaged in Combination," in two parts.]

Aug. 31st, 1850.

To Miss Graham,—I started from London on Tuesday night, and in twenty hours reached Cologne very much cut by sea-sickness and fatigue. But after a night at the Hotel Hollande I was quite recovered, and enjoyed the sail up the Rhine in a very fair day, the voyage to Biberich near Mayence lasting from 6 to 7 evening and reached Frankfort by railway about ten: when I got to a good hotel, "the Roman Emperor," the town being crowded from the fair. The peace people had left. Cobden had been most admired, and the people here had been gratified by the discursive style of English addresses which they take as a lesson in public speaking. Next morning I went on by railway and diligence to Giessen, from 9 to 2 p.m.; and after dining at the Rappen called on the Professor. He appeared to me in better health than the reports, indeed I would imagine quite as well as when I first saw him thirteen years ago. He had many inquiries for you, and has made up his mind that you are to come and spend four or five

months with them. Madame Liebig and part of the family are at Ostend, he had waited a day or two on my account, and then Dr. Will and he proceed to Aix-la-Chapelle to analyse the waters—a professional engagement. I found the leading young chemists of the place still here, Dr. Strecker whom I think very highly of, Flutmann, and Will. Kopp had already left, but Knapp and Madame Knapp were at home; also an Austrian young professor Dr. —we had a very merry supper party. Dr. Hoffman I also found at his mother's, and was introduced to the old lady and his two sisters, a very pleasant family circle. They know you very well through Mrs. H.; she had left again for Darmstadt after a visit here; she, I understand, is very well. The doctor however has not made so much ground as he should have done. We shall be occupied all this day (Saturday) about Giessen, then Dr. W. and I go to Marburg to-morrow (by rail) to see Bunsen. On Monday we propose starting with his married sister for Frankfort, next day to Darmstadt, and Wednesday to proceed direct to Switzerland. If you should write a line, it would be best to address me to "*Post Restante*" Berne.

The season in Germany has hitherto I think been scarcely equal to England. This, however, is a magnificent day, and they hope for a warmer Autumn.

I am living with the Professor, and have the world of news and information. You will be glad to hear that he is entirely reconciled to Dumas. They had met and spent a few days together, at Lille I believe. The minister of commerce had in command from the president to present the decoration of the Legion of Honour to the Professor. Liebig will be over for ten days at Easter to see the great Exposition, with every body in Germany, and intends to bring Madame Liebig.

[Between 1844 and 1855 Graham was at work on ten papers —eight on small matters, but two of great importance, being his celebrated papers on the "Motion of Gases," and the "Diffusion of Liquids."

In 1855 Graham succeeded Sir John Herschel as Master of the Mint. On his appointment to the Mint, he laboured assiduously and successfully in acquiring a thorough knowledge of the technical work and financial relations of his office, and discharged his duties with much energy and judgment. It is known that he brought about various reforms and economies in the working of the esta-

blishment; but the service for which he will be chiefly remembered was the introduction of the new bronze coinage, which, besides substituting a more convenient medium of circulation than that in previous use, was attended with a pecuniary profit to the State of very large amount.]

The Mint, Nov. 7th, 1855.

To Miss Graham, Nice,— . . . . I have not happened to remark anything of late respecting the state of Rome and other Italian cities as regards cholera, but if they are suffering from an autumn attack that is likely to be on the wane. I shall send, however, a few daily papers to Nice, and if matters are really bad you are likely to find some notice of them.

We are keeping up our high rate of work (£420,000) weekly at the Mint, although it requires constant vigilance on my part, particularly in the absence of Mr. Barton, whom I wish to make out his month's holiday undisturbed. He returns in a day or two. . . . .

London, Dec. 1st, 1855.

To Miss Graham, Rome,— . . . . I hope you will find a healthy, comfortable apartment, and would recommend you not to be too parsimonious on that head.

Here things have been going on much as usual. But I have one surprise for you. Dr. Lee, of Hartwell, has just married a lady of twenty-five. The first news of the happy event, coming through Admiral Smyth, was set down as a joke, but it has been published since in the *Times*. At the Royal Society Anniversary Dinner yesterday, where I first heard this, not a bad joke was current respecting the new Lord Mayor's dinner, Salomons, being, you know, a Jew. One of the city waiters was addressing the visitors—"Gents., would you have fish," and when Baron Platt remarked that it was too bad to address judges in that manner, his neighbour at table asked if the Baron did not know that "Gents." was short for Gentiles!

Faraday called at the Mint, looking uncommonly well after a sojourn of three months at Brighton, and in first-rate spirits. He had many enquiries about you. Sharpey also appears to be somewhat better in health.

Playfair says that Lord Palmerston does not look favourably upon the decoration of the English jurors by the Emperor, and that the crosses will be somewhat contraband on this side of the channel; it is the aristocratic feeling coming out.

I should mention that Lord Wrottesley, notwithstanding his omissions of the *soirées*, is giving much satisfaction as President of the R. S. The two Royal medals were given one to Hind, Mr. Bishop's Astronomer, and the other to Westwood the Naturalist. The Copley medal to M. Foucault (pendulum movement, showing rotation of the earth, &c.) I dine to-day with Dr. and Mrs. Arnott to meet the latter. He made a pretty French speech at the Anniversary Dinner, where, by the way, I was myself called up, Sabine giving me the alternatives of proposing the health of the President or returning thanks for "Her Majesty's Ministers," of which I preferred the former. . . . .

Dec. 13th, 1855.

To Miss Graham, Rome,— . . . Dr. Hoffman had an accident to his eye which was at first a little alarming, and got, I believe, into the newspapers. The Rev. Mr. Barlow had caused an explosion of sulphuric acid, a small drop of which found its way past the glasses into the Dr.'s eye. He was confined to a dark room for a week or ten days in consequence of the inflammation, but is now going about again without having suffered any permanent injury. You may imagine what a vexation the accident was for poor Mr. Barlow, who attended at Fitzroy Square like a nurse. The Dr. promises a musical party as an opening of the house; the furnishing goes on gradually. At the Mint we have continued to keep up to our six deliveries a week (£430,000), although unusually troubled with unworkable gold, of which I was obliged to complain to the bank. The mischief I have since traced to a small quantity of iron in the gold, which is that of "Ballarat" and the "ovens" simply melted down, whereas it ought to be refined before being sold to the bank and sent to us. The bank melters, Brown and Wingrove, promise to look after this in future. I am gradually and quickly suppressing the abuses of the coining department, and Mr. Brande now submits to my innovations with resignation if not with a particularly good grace. They were

chiefly ridiculous extra charges which the men had been allowed to make, the passing of which every week was a recurring vexation which I now escape. . .

Jan. 8, 1856.

To Miss Graham, Rome.—I had your long and amusing letter giving your visits to the Cardinals and French Commandant, for which many thanks. It has since been forwarded to Cooper at Southport. On calling on Mrs. Wilkinson, a few days ago, to deliver your message, I received an emphatic contradiction from her of the report that Dr. Wiseman was going to Rome. She rather opened her heart to me on the occasion, telling me that she is the only Catholic convert in the family, her husband having lived and died—"poor man"—a Protestant clergyman. Her brother Mr. Porrett, is High Protestant also, and a little intolerant, so that the good lady holds to her adopted faith under what she considers no small persecution. She was present at Oscot College when Mr. Talbot was first received; he gave up an English living. When she was fifteen or sixteen, the father of Mr. Hemans was devotedly attached to her, but afterwards married Felicia. She saw a young man once at Oscot Church, in whom she recognized the form and features of her old admirer, although the young man was shorter and not so good looking; this is your Mr. Hemans. She is very well and sends her compliments.

I got tolerably through the holidays all things considered. First—I went to a German tea, with which No. 9 Fitzroy Square was inagurated, but here made two mistakes—dining beforehand, for the repast was of a most substantial character, recalling the tea-dinners of primeval times. The other, for which in some degree I must blame the Doctor, who had put at the bottom of his invitation, "evening dress with decorations," was appearing on the occasion in white choker, black coat, buttoned up to the throat, and the Rosette and Star of the Legion of Honour blazing on the left breast. Coming late and proving to be alone in my glory, the effect upon the company, and especially the female portion of it, was magnificent, perfectly stunning. The Dr. himself had not mustered courage for such an exhibition, and there was no other *decoré* present. Miss Hoffmann is evidently more comfortable in their own house than she was formerly in her brother's lodgings.

Secondly—I ate my Christmas dinner at W. Tookes, Russell Square, who has lots of grandchildren, and had the honour to take out Mrs. Arthur Tooke, an old Pau friend of yours. . . . . Also, old Thomas Tooke, the distinguished political economist, Dr. Gray of the British Museum, and a remarkable lady whom I must not forget, Mrs. Grant, who has been to Pau and everywhere; she has a daughter a Ward in Chancery, whose property Mr. Tooke manages. Mrs. Grant has been presented to all the Queens of her time I believe, and discussed the royal bearing of each. She is not altogether satisfied with the Empress of the French, who is a nice gentleman's wife, but wants *fierté.* The Queen of Spain disgusted her. She pronounces our own Queen, little as she is, to have dignity, and to look the Queen more than any of her compeers.

It is a little curious to find myself taken into council by the Government on financial questions, and to be talking over affairs of state with the Chancellor of the Exchequer and Secretary of the Treasury, over a parlour fire in Downing Street. The fact is, that finance at present offers a magnificent career if one could give up Chemistry; but no, I must remain true to my first love.

Paris, 3rd Oct., 1856.

To Miss Graham,—Pelouze was at his post, and from him and the contractor at the Mint I have every information that I can desire. We were to-day at the manufactory of MM. Rousseaux, and saw the production of both sodium and aluminum on a grand scale.

I shall have scarcely occasion to go beyond Paris, and will probably remain over the meeting of the Institute on Monday. I propose to take Brussels on my way back.

30th Dec., 1857.

To Mrs. James Reid,—The five-pound gold piece was struck expressly for you as a *souvenir* of the Mint. It is considered one of Wm. Wyon's best works. "Una and the Lion," and such pieces are so scarce that they bring a good premium. I am only afraid that the gold will burn in the pocket of such a thrifty person, and that you will be disposed to realize.

[From 1855 to 1861 Graham published nothing of importance, when in that year appeared his celebrated paper on "Liquid Diffusion applied to Analysis."]

16th May, 1861.

To MISS GRAHAM,—The issue of the new bronze is going on satisfactorily, all that is manufactured being out or bespoke.

Last week has been a week of *soirées*. I could not avoid being out every evening. Among the rest Lord Ashburton's, as President of the Geographical. I had not seen Lord A. since his marriage. He introduced me very kindly to Lady A. Wild, you will be surprised to hear, has given up his office at the Royal Society. There is some difference between him and the other (superior) officers, which has not been explained. He certainly was not generally liked.

I was able to send in a paper to the R. S. last week, which contains two or three years' work, and has cost no small effort to get up amid my other distractions. I need only describe it as 98 folio pages in length. I expect also to hand in two short ones, all but ready, before the recess. This is an unspeakable relief to me, for nothing depresses me so much as the falling behind in my scientific career, consequent upon my official engagements; but I hope to recover in some considerable degree my place in the race by these papers.

17th.—I had a visit to-day at the Mint from Prince Arthur, a fine bright boy. He certainly promises well.

7th June, 1861, from London.

To MISS GRAHAM, Pau,— . . . I forget if I told you of the last move of the officers of the R. S.—it was to place me as Treasurer and Vice-President in succession to Sabine, the latter being elevated to the chair. This would have suited me better, as the duty would have been light; but, after some hesitation, I have felt it necessary to decline this also. W. Crum and Dr. Hoffman agreed with me in the propriety of this resolution. Sharpey is, however, much disappointed, as he had set his mind upon such an arrangement, which he says would have made Sabine's presidency go down better with the body of the Society. But the overwork

of last winter and spring has made me nervously afraid of encountering engagements merely for honour's sake. My chemical work, on the other hand, is going on very nicely. . . .

4th Nov., 1861.

My Dear Master,—I am very glad to be able to inform you that Lord Palmerston has sanctioned the appointment of your brother to the office of senior clerk and assistant coiner in the Mint.

This may be attributed not only to the testimonials of superior fitness for the office which your brother possesses, but I hope that you will also consider it a mark of the estimation in which, for your services and the economy you have introduced into the department over which you preside, you are held.

Believe me,
My Dear Master,
Very truly yours,

The Master of the Mint.

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7 Nov., 1861, from London.

To Miss Graham, Pau,—I am enjoying my holidays, after a way. The change in the weather, wind and snow, sent me up from Hastings after a few days. The business at the Mint has been brought up so that things can go on for a few weeks without my intervention. Mr. Barton and John have it all their own way, and I believe both will be improved by the responsibility. In the meantime I fully enjoy my temporary release.

The election of President of the Royal Society comes on upon the 30th inst. Dr. Roget is still urgent for Lord Brougham, and he will be proposed. The election might, I believe, be easily secured by a little organization among his supporters. It would be an appropriate close to the career of the old hero. In the meantime, from necessity as well as choice, I keep myself entirely out of the melée.

In making holiday I looked in at the National Gallery yesterday and found Mr. Wornam the Director. The change is surprising.

That Turner room is really a National treasure. I wandered out afterwards to the Zoological where I met Lewis with "George Eliot" on his arm. I had never seen the lady before, she has a long face, and her attractions do not reside in her looks—so far for first impressions. Last week I had a very agreeable communication to make to Mr. Aitkinson and University College. My old friend Mr. Evans of Worcester (Hill and Evans, the vinegar makers) gave me the first intimation to the College, of a small legacy to U. C. under a will of which he is one of the Executors. It is about £60 per annum, without any restriction. The testator was an old gentleman of the name of Webb, 90 years of age.

9th Nov., 1861, from London.

To MISS GRAHAM, Pau,—The issue of the new bronze pieces goes on successfully, and we have the public with us. The change from the old to the new will, I believe, be roughly completed within the Metropolitan district in the course of a few weeks more.

11th Dec., 1861, from London.

To MISS GRAHAM, Pau.—I have obtained another senior clerk, a kind of deputy to John, principally for the outdoor work. He is a Mr. C. F. Macdonald, of Manchester, who was recommended to me by George Wilson, and of whom Mr. Gladstone had also heard from other sources.

In this business I have allowed an extremely simple system to develope itself, which has kept the work falling on the department at a minimum, and procured us an amount of gratuitous assistance all over the country which is really surprising. We have had nothing to retract, had no mishap of any kind, and every step we take I see my way better, and can advance more confidently.

. . . I have had letters from old chemical friends respecting my paper, which is being translated into German and French, and find that it is attracting attention. Professor Schönbein, of Basle, writes an amusing letter.

14th Dec., 1861, from London.

To Miss Graham, Pau.—The bulletin of the Prince Consort's health is favourable this afternoon. Dr. Arnott says that all ground for uneasiness has ceased. Lord Monteagle, with whom I was talking, says that so serious did things appear yesterday that the Duke of Cambridge was called away from parade.

Miss Coutts has been to Compeigne, and reports the Emperor as speaking strongly against the Americans. He wished they had tried it on one of his ships.

16th Jan., 1862, from London.

To Miss Graham, Pau.—Doctor Hoffmann has had a tempting offer of a Chemical Professorship at Bonn. His countrymen are anxious to have him back, which I can well understand. I was telling him his countrymen must look upon him as the "missing planet" between the orbits of Bunsen and Strecker. He was much shaken by the offer for several days, but he is too well situated in every respect here to make a change.

James Young, with John Thom, Dr. Angus Smith of Manchester, Dugald Campbell, and John, dined here the day before yesterday. The gathering was due to Mr. Young's friendly anxiety to support the claims of Dr. Smith to the Chemical Chair in Aberdeen, which has become vacant by the death of Dr. Fyfe.

In case the Rev. Mr. Yorke should be disposed to look into a correspondence on the glacier question, I beg to enclose a letter from Professor Hopkins, the eminent Mathematician and Physical Geologist, who is to lecture on the subject at the Royal Institution on the 31st., with my explanatory reply. I do not care to publish more on the subject till I have had an opportunity of making a few experiments to illustrate the subject.

3rd February, 1862, from London.

To Miss Graham, Pau.—Since I had your last favour, Professor Hopkins' lecture on the glacial theories came off at the Royal Institution. It was very clear and satisfactory so far as it went, but of too elementary a character to take up such a point as the

colloidal condition of ice. It was entirely decisive against Forbes's confused views of viscosity. A peculiar idea was brought out by Mr. Hopkins to account for the glacier movement, so far as it is a sliding motion. He had observed that when a block of ice is placed upon a plane, such as a Welsh slate, slightly inclined, the ice will slowly move downwards. This slipping motion was admitted to depend upon the melting of the lower surface of the mass of ice in contact with the slate. But whence the heat to melt in such a way the bottom of a glacier? The internal temperature of the globe to be sure. The Professor had a mass of ice placed as described on a slate, to show this motion, but somehow or other it was "no go;" but Faraday, the moment the cause of the expected movement was given, darted off, and placed a gas lamp below the slate, thus bringing in the "central heat" with a vengeance. The movement speedily followed. There may be something in this motion of Hopkins', although the prevailing opinion is that the effect of the central heat upon the surface of the globe is too small now to be appreciated. But the rocky bed of the glacier is scratched, showing a sliding motion; to which it may be replied again, that the bottom surface of the glacier ice itself has been found scratched also—not melted away as the hypothesis seemed to require. Mr. Hopkins, however, insisted most upon the crushing of the brittle ice, and its subsequent "regelation" into a homogeneous mass in its new position. Dr. Tyndall's pretty experiment of crushing the ice into the form of a transparent cup by a Bramah press was successfully repeated. And here the lecturer stopped. Mrs. Faraday had her enquiries for you. She reports Mr. F. as pretty well, "but we must not let him work so much as he would like." The Bucktons were also enquiring for you.

While we are scientific, I may refer to Mr. Yorke's problem of the brandy cherries and your own preserved greengages. The sugar and much of the flavouring material come out and are distributed through the brandy. It strikes me that the thing would be made plainer by using a little bag of animal membrane (or parchment paper) instead of the greengage. Supposing the little bag was tied up filled with gum-water, and placed in the bottle of brandy. The first result would be (I believe) that the water would go out to the brandy, which greatly attracts it, and the bag would collapse. The difficulty of the brandy entering the bag is greater than that of the water leaving it. But in a certain

time the proportion of brandy would be the same inside and outside the bag, the latter still much collapsed. So it would end were it not for the gum in the bag. Gum is one of those substances which cannot get through the walls of the bag (gum being a colloid), and must therefore remain there. But the imprisoned gum now attracts water to itself from without by *endosmose*, and the consequence is that the bag is again distended, the gages become plump at last. The water that has so got in is also followed by alcohol, attracted by the water.

You refer to the sad coal-pit accident. Some one has cut out of a paper and sent to me the enclosed slip. It was an old idea of mine, but the material mentioned should be kept in store in all mines liable to choke-damp. But still, it is the old story, the life-boat not at hand when wanted. The surest guarantee against such accidents is the Scotch law, which gives to friends of the miners an action against the mine proprietor. In Scotland each of the widows would have thus received, at least, £250.

14th February, 1862, from London.

To Miss Graham, Pau,—He (Mr. John Graham) is very much engrossed with our bronze issue, which is truly a considerable affair. It requires a great deal of attention, but goes on prosperously.

Last Friday evening we had an interesting lecture from Professor Huxley, at the R. Institution. The great point was producing a human skull from the bone cavern—the skull of the man who made the flint implements found in the drift. It appears that the skull in question was found so long ago as 1830 or '40, in a bone cavern near Liege, and was described by a good native geologist as being contemporaneous with the accompanying elephant and tiger remains; but nobody believed it. Lately, however, Sir C. Lyell went into the question, and on re-examining the skull, found it to be in exactly the same fossil condition as the other bones, and manifestly of the same age. It was a fairly formed skull. Next Friday evening Dr. Odling is to illustrate "Dialysis." Calvert, of Manchester, lately gave a lecture there on the same subject. Redwood followed.

Saturday was the private view of the picture exhibition of the British Institution, which I would not like to miss. It is a kind

of harbinger of Spring, the snowdrop of exhibitions. There I met old artistic friends, Wornam, D. Roberts, your Caucasian admirer Solomon Hunt, R.A., &c. It was a pretty show, remarkable, as usual, for the large number of fair pictures, rather than for any salient production.

19th Feb.—I have allowed several days to elapse. Odling's lecture I hear from all quarters went off exceedingly well. The subject admitted of a number of pretty experiments which he made the most of. I dined on that day with Bence Jones, found Col. Thos. Yorke, Dr. Hoffman, a Miss Raphael or Gabriel (I forget which angel), a clever creature and great favourite of our host. The Franklands were expected, but by some accident did not come although they were at the lecture with Miss Colvill afterwards. I had also a quiet dinner with Dr. Sharpey last week, to meet a brother of Professor Kölliker's, who is, I believe, a Swiss merchant. All your friends were enquiring for you. Miss Hoffman is still very weak, and has not come down stairs, but I was admitted to a visit. She also desired to be particularly remembered to you. Their sister, Mrs. Raw, is with her. James H. and Carl are both well. The Dr. has cleared up lately with great success the nature of the magenta colours, which was very obscure. The amount of good work he gets through is something extraordinary. The printed copies of my *second* paper came to hand to-day. It is a much less general subject than the last, and not of the same popular interest. But I shall post a copy to you.

I am drawing up my report on the Hong-Kong currency, which seems to drive everything else out of my head for the time, and is the only apology I can offer for scarcity of news.

[In 1863 appeared Graham's paper on "The Molecular Mobility of Gases and Atmolysis"—the remaining years of his life being chiefly occupied by this subject and that of the occlusion of gases.]

11th Feb., 1863, from London.

To Miss Graham, Pau,—I am getting a head of the Queen engraved by a German artist, C. Weiner, who has come to settle in London. His first attempt is certainly good as a likeness, but too realistic to please. He will probably try again, and if a portable impression can be taken, I shall send it for your opinion. Weiner's designs for the Rumford medal met with a qualified

approbation only in the Committee of the R. Society. The Committee included Sir C. Eastlake and Mr. Westmacott, the sculptor, who pronounce rather decidedly against the *taste* of the work. Weiner has improved the designs greatly, acting upon suggestions of Mr. Westmacott, and it will now probably be passed. The old dies to be superseded were quite wretched.

9th May, 1863, from London.

To Miss Graham, Pau,— . . . . The fact is I had an evening occupation for the last two months which has nearly excluded everything else, correspondence in particular. It is the composition of a paper for the R. S., embodying several years' work—the subject, the Gases—which I was very anxious to get off my hands. It has cost more work (I mean investigation) than the dialysis, but is necessarily a little mathematical, and consequently less generally interesting. I am glad that it is now off my hands, having been delivered in fairly copied only last evening. . . .

I had a few words with Playfair last night, who had just returned from Osborne. He describes the Queen as in fair spirits, and able to speak of the late Prince, which she is constantly doing, without suffering. He is very thankful for the information you sent him respecting the education of his boy at Pau. It was a meeting of the Chemical, and I found Stenhouse there, remarkably vigorous. Hoffman also in great force.

I have avoided any inquiry about the Bonn business. It seems publicly rather to have passed over. Stenhouse gave the general impression that the Bonn salary, about £400 a year, would be insufficient for the Dr. after his London experiences. I am to dine with him next week at Mrs. Wilson's, and then may perhaps hear more of his intentions. There is a little stir just now with the appointment to a new office, the Inspector of Chemical Works, for which Dr. Angus Smith, of Manchester (James Young's friend), is the favourite candidate. Young was in town, and went with me to dine at the R. S. club. He considered himself very fortunate on the occasion, as he was placed between Sir Wm. Armstrong and Sir R. Hill. He had been in Glasgow, and spoke favourably as to Mrs. Reid's health. I have not heard anything direct from Blythswood Square for a long time. I accepted an invitation from the "divine Rachel" to visit Bushey Park and see the

chestnuts next Sunday afternoon, dining afterwards with the Chadwicks, at Richmond. I have been little out for some time, but I dined last Saturday with Dilke. Except Willis, of Cambridge, and myself, the party were chiefly old family friends. The President's *soirée* followed, at which the Prince of Wales made his appearance. Dilke says, by the way, that the Queen has spent a great deal of money lately, that she insisted on refunding all the Danish expenses from Copenhagen to London, also the Hessian, "because they had not the money to do it." It appears that the English officers who escort on such occasions receive large *douceurs*, two or three hundred pounds. She also paid the hotel bills. Being in mourning, she did not receive the visitors in Buckingham Palace, which explains why her visitors were in hotels. . . Enclosed you have a little piece for Hong Kong, a thousand in a dollar, or twenty in a penny. . . .

[This completes the letters of Graham, who belonged to a group of chemists of the first rank, whose education and experience were entirely acquired on British soil, and, moreover, of a group of chemists whose powerful generalizations materially advanced the science throughout Europe.

The matter which follows is exactly as written by Dr. Angus Smith, and appears to call for no further remarks by the Editor.]

As a private man Graham led an uneventful life; but no man has passed through the world more uniformly respected. Too retired, too quiet, his life appears to have a deep tinge of melancholy in it, notwithstanding its eminent success. Very intimate friends he had few out of the circle of the family of brothers and sisters, who were strongly attached to him, and to whom he was much devoted, being himself unmarried.

It was by Dr. Thos. Thomson's teaching that Graham first learnt Chemistry, and however much his boyish mind may have been attracted by the wonders of experiment, it was at a very early age I believe that he began to think of the recondite laws of matter. In 1826 there is a memoir by him on the absorption of gases by liquids, and his shrewdness and calm mode of speculation are as apparent there at 21 as at any time of his after life. He supposes for example that absorption and liquefaction of gases are regulated by the same fundamental properties.*

* Faraday's experiments on the liquefaction of gases were made in 1823. [ED.]

Next year, viz. 1827, speculating on the atmosphere, he thinks that it may become liquid or solid when cooled to 284°C. He says that if the air cools at the rate of 1 degree for 300 feet, it may lose its elasticity at 27·27 miles, and temperature occasion a limit to diffusion. Here then we almost say we find him beginning his work, and next year we have a memoir by him on the absorption of vapours by liquids, and another giving an account of experimental researches on the diffusion of gases, seizing boldly the subject as it was left by Dalton and others.

In the same year we have the nucleus of his work on the diffusion of liquids. This I consider to be found in his paper "on the influence of air in determining the crystallization of saline solutions."

Whilst he was speculating on laws of liquids, vapours, and gases at this time he was also very much occupied with practical ideas, and one would almost have expected from his note book to see him come forward as a manufacturer, or what is now called a Chemical Engineer. Some of his thinking is to be found in *Chalmers's Journal*—referred to in his letters—when it was published monthly in small octavo, and even then able to say that "from the highest to the lowest, the various ranks of the community appear to vie with each other in the acquisition of all that in Science and Literature hath a practical bearing on their convenience or comfort." In the first number, page 25, we have a short article on the great weight of charcoal, signed G., and showing some of the remarkable transformations of that element. There is also an article on the advantage of copper bolts in soldering.

Another short article is a proposal to use a sand-bath as a cooking apparatus, an idea that might readily come from a chemical student in early days. This seems to have pleased the readers of the *Journal*, and brought out in number 2 a longer discussion of its advantages. He recommends also that ladies should have for themselves, outside of the kitchen, a sand-bath for "the more delicate and interesting processes, and to present to our countrywomen a fair field for the exertion of their culinary powers, unencumbered by the coarser details of the art." A drawing is given in the third number, and thanks presented for the encouragement he had received. In this number—that is, number 3, page 121. May, 1827—there is an article by Graham on a "Marine Amulet or Life-preserver, on a new principle." This is the production of

carbonic acid in an air-tight bag. The bag may be put round the body, and take up so little room as scarcely to be felt or seen, but the moment it is immersed in water a valve opens, and allows a certain amount of water to enter. This enables an amount of tartaric acid and soda bi-carbonate to act, and the bag distends, A bag capable of holding a gallon, when distended, is filled to the extent of one-third in ten seconds by using half an ounce of each of the powders. It is worth while giving this more fully. The production of buoyancy is a most valuable quality, and if we can so apply gases that the act of foundering produces the means of elevation, we have gained a great point. May this principle not be employed to raise sunken vessels?

The following is the account given of "The Marine Amulet" in *Chalmers's Journal of Useful Knowledge and Monthly Miscellany of Arts and Sciences,* 1827.

"The instantaneous production of a large quantity of air is familiar to everyone in the case of mixing the solutions of soda powders. Could such an evolution of buoyant gaseous matter be made to take place in a proper recipient, and without trouble, upon the occurrence of an accident, a life-preserver, correct in principle, would be obtained. This principle might be applied in different ways, but perhaps the following is the most simple:—

"A bag of Macintosh's water-proof double cloth, of cotton or silk, being procured, and found upon trial to be air-tight, a collar of strong and stiff leather may be fixed to the mouth of it. This collar should be three or four inches long, and of a flattened construction, perhaps two inches across in one direction and three-fourths of an inch in the other. The open mouth would now be closed with a valve or lid, *opening inwards.* The valve or lid would, of course, be as wide as the collar, or two inches by three-fourths of an inch. Supposing the bag to be capable of containing four quarts, or a gallon, a quantity of the soda powders, amounting to half an ounce of each, may be intimately mixed, and introduced into the neck of the bag, still dry, by pushing back the valve. The apparatus may be then fixed to the person, the empty bag stretching across the breast, and the flattened neck or mouth being brought out from beneath the waistcoat at the right side, so as to be easily got at by the hand should that ever be necessary. As, when the apparatus is so arranged, the collar would be in a position somewhat oblique, most of the powder would rest upon the interior side of the collar, and not press much upon the valve, which would

therefore be loose, and probably not altogether shut, although sufficiently so to retain the powder. A sudden plunge into the water would therefore be unfailingly attended by a considerable insinuation of the liquid into the neck of the bag, the valve yielding inwards to the stroke. But the moment that water comes in contact with the powders they violently react upon each other, producing a copious evolution of *incoercible air* [carbonic acid gas], which would violently press down the valve, and inflate the bag with considerable force. We have found by experiment that the bag, in such circumstances, is filled with air to the extent of at least one-third, which is enough to render a man buoyant within ten seconds; in twenty seconds the bag is more than half-filled, and within a minute it is completely filled, and all perceptible action at an end. Should a person invested with such a preserver be accidentally thrown into water, the air-producing apparatus would be brought immediately into action, and the bag forcibly inflated, although previously it had been flaccid, and had occupied very little space.

"The collar which is appended to the bag, and the valve or lid, which are the most important parts of this apparatus, might be constructed of various materials, and of any shape which was found most convenient. The most important circumstances to attend to are, that the neck or collar be of such materials as would not readily collapse or close together from external pressure, and that the valve be of considerable size, and such as would admit the water with ease. Should it be thought advantageous to admit more water than has entered at the first rush, the valve could be pushed inwards by the hand near it, and more water would enter; or, if it was perceived that more air would be produced than was necessary to inflate the bag to its full dimensions, from too great a quantity of the powders being employed, a momentary opening of the valve would remove the injurious excess. From the construction of the apparatus, and the manner in which it is attached to the body, it is evident that when in actual use in the water, the inflated bag would rise and maintain a superior position, while the collar and valve would be constantly under water—an arrangement which would secure the retention of the air in the bag. The air, too, within the bag would not be in immediate contact with the valve, which would be protected and made certainly air-tight by the water which had entered and induced the action."

At this point it is remarkable how varied was the action of Graham's mind, both in practical and theoretical Chemistry. But, perhaps, chemists are, by the nature of their studies, driven to a greater variety of subjects than most other men. It may be interesting, however, to remark, that we find in the note-book, 1827-1828, reasoning on—

Nitrification, ...	page 1.
Sulphuric Acid, ...	16.
Steam	25.
Steam-engines—Cylinder—Piston.	
Steel Pens.	
Miscibility of Gases.	

On this point, his note-book contains the following at page 144—"Dalton's theory, of the tendency of gases to mix with each other, that they are vacua to each other, is faulty, as it would occasion an instantaneous and complete mixture, which certainly does not take place, and I have shown previously that cold could be produced on mixture as a necessary effect of Dalton's supposition, which I have found on trial not to be the case. The gases must, therefore, actually press against each other. Aqueous vapour in the atmosphere must be pressed upon, and be really as dense as the atmosphere.

Suppose a vacuum made in the receiver of an air pump, as nearly perfect as possible. Admit a little water, the vacuum would be filled completely with aqueous vapour of light tension, upon admitting air into the vacuum, the first effect would be to drive the aqueous vapour before it, compress and condense it. If the bottom of the receiver was not dry, aqueous vapours would rise without the artificial introduction of water, and it is probably the condensation of such vapours which occasions the haziness often observed on the entrance of air. This, of course, is quite contrary to Mr. Dalton's theory of vacua."

It is interesting to see one of his earliest private thoughts on this subject, but, also curious to find that he, like many others, had not entered fully into Dalton's mind on the subject. Dalton never doubted that one gas could drive forward another, as a rod of pine would drive forward a rod of oak if pressure were suitably applied, although, at the same time, he never could clearly express the mystical relationship which he supposed each gas to have to

the particles of its own kind. Graham too had not made clear to himself at this time the distinction between specific gravity and tension.

The same note-book speaks of Phosphates, Iodides of Carbon, Alcohates, Salts of Magnesia, Atomic weights, and Combining Volumes. I think he must have been early on this subject. Then we have the absorption of salts from solution, evaporation of saline solutions, water of crystallization, a subject on which he spent much time; Howard's patent for sugar boiling, Perkin's ideas of steam, and a plan for an Academy of Science, with some other discussions.

When Graham came to Glasgow, in 1830, to lecture at the Andersonian University, after he had been some time in Edinburgh, there was a good deal of interest excited about him, and I fancy this was felt more by the boys than the general population. I was told by a boy, now pretty far advanced in years, that a wonderful young man had appeared, one who, although only nineteen years old, had still a great reputation. I went to hear one or two of his popular lectures, and I remember his looks well. He might have been taken for nineteen, but, in reality, he was twenty-five when he first lectured at the Andersonian. He had the same quiet, rather stiff, and hesitating manner which he never lost. He did not cause enthusiasm by brilliancy of address, but a certain reserve and a certain feeling of power, as well as of ambition, which his letters prove to have been strong in him, so acted on his demeanour, that students became attracted, and were ready to work beside him and devote themselves also to his service. Amongst these was James Young, of paraffin oil celebrity, who, from a student, became an assistant, and played a part in the industrial world which was not less remarkable than his teacher's part in the scientific. I remember hearing him also spoken of as a very wonderful individual, but I remember little more, as he stands out before me, chiefly as a head sufficiently red and uncombed, by no means like the smooth yellow hair of his middle age, or the venerable white of his later years.

When Graham first lectured here, it was certainly to an audience ready in interest, a Mechanics' Institute had been formed some years before, and the University was proud of Dr. Thomson. Dr. Ure, a man of great mental activity and power, a man who might have been a force in Europe, preceded him in the Andersonian, but lost his position by attending too much to his interest. It

was pleasant to find a young man who took an interest in young people. I well remember how far the sympathy went. One of my playmates, Edward Craig, became a small walking laboratory, his waiscoat pockets had each a range of several small vials. He had no test tubes, beakers, or basins, he asked us to put out our hand and to make it as hollow as possible. Into these "loofs" he poured his solutions, made precipitates, solutions and smells. That boy made more than one chemist; he himself did not continue the subject, but next year had his pockets full of abridgements of Locke, Bacon, and others, and on these he raised many discussions. Nothing came of Edward Craig, he had too little ambition in any direction. This was a little offshoot from the scientific schools.

Graham's direct influence was exercised in a manner which I rather think may be called quite new. I incline to call him the founder of the practical system of teaching Chemistry, at least in this country. Liebig was two years older, and opened his Giessen Laboratory in 1826; Graham began his very naturally, and not by imitation. His pupils wanted work, and he gave them his to do. He early got into a very languid mode of life, owing to simple constitutional want of elasticity. The work on water of crystallization was all done in these early days at the Andersonian, whilst Graham himself sat looking at the fire in weather not at all wet or cold, too languid even to look at the experiments. But the cause of this was partly mental. He was often in great straits for want of money. Once he required a silver crucible to make some experiments for a commercial firm, but he could not buy one and he was refused credit. In that Laboratory were taught some chemists of which Glasgow might be proud. Dr. Stenhouse, who lately died, may be mentioned first, as a man of great force of character and wonderful energy, who has left numerous results of his shrewd enquiries in botanical chemistry. Sir Lyon Playfair and Dr. Gilbert being still in full vigour, I shall only allude to them; the same may be said of Mr. John Thom of Chorley, who in reality did the experiments which based the theories of constitutional and saline water. The Griffins made a departure in another direction of no small advantage to the community, and the family still continues their important services to chemists. Crum and Harvey are still great manufacturing names in Glasgow. These names first showed themselves as attached to chemists in Graham's Laboratory. Blyth and Thom still hold their ground as

great manufacturing names in Lancashire, and promise to continue to flourish.

As a scientific man, his claims were never disputed; he was not called to assert his position, and he remained the undisputed head of his department. He received in early life (1834) the Keith Medal of the Royal Society of Edinburgh, and the Royal Medal of the Royal Society in 1838, and in 1862 the Copley Medal. He was made a Doctor of Civil Law of Oxford, Honorary Member of the Royal Society of Edinburgh, Corresponding Member of the French Institute and of the Academies of Berlin and Munich, and of the National Institute of Washington. His election into the Royal Society was in 1836.

In 1841, in concert with some friends, he formed the Chemical Society of London, and was elected its first President.

Graham's Chemical and Physical Researches: an Abridgment of Thomas Graham's Work, containing an Abstract of all his Papers.

GASES.

I.—Absorption of Gases by Liquids—1826.

From "Annals of Philosophy," xii., 1826, pp. 69-74.

Liquids miscible in all degrees, as alcohol and water; or in limited degrees, as ether and water. Some mixtures exhibit chemical union. Water impairs the volatility of alcohol. Gases may be considered volatilized liquids, and such bodies may have the common properties of liquids.

It is assumed then that gases liquefied by pressure or other means will mix with liquids in some proportion. Sulphuric acid, at boiling, or 600° F. (316° C.), will liquefy steam of the same temperature, although it would require to pass down to boiling point to be condensed. Gases may owe their absorbability to their capability of being liquefied.

Gases already liquefied, by Faraday, easily absorbed.

The sp. gr. of the liquids formed, and of their solutions, are confirmatory. Dr. Henry's law, that absorption is directly proportional to pressure at variance, *ex. gr.*, in muriatic acid, but may be approximately true when absorption is small.

By diminishing temperature we diminish the absorption of a gas, not in the same but in much greater proportion. Amount

of gas absorbed by a liquid depends on the gaseous residue or amount of gas exposed to the liquid. This is deducible from the gases being liquefied. Analogous instances occur with liquids.

Finally, absorption of gases is in the same class as miscibility of liquids.

II.—On the Finite Extent of the Atmosphere—1827.

From "Philosophical Magazine and Annals of Philosophy," i., 1827, pp. 107-109.

Wollaston's opinion that the limit of the atmosphere would be arrived at on mechanical principles. Faraday's illustration. But it may be that by being cooled down to 284° C. it becomes liquid or solid. If the air cools 1 degree for 300 feet it will lose its elasticity at 27·27 miles, and temperature occasion a limit to diffusion.

III.—Longchamps' Theory of Nitrification, with an extension of it—1827.

From "Philosophical Magazine and Annals of Philosophy," i., 1827, pp. 172-180.

Reason to doubt Glauber's theory, the prevailing one, that "saltpetre is formed by the decomposition of mineral and vegetable substances."

The solution of lime, by the free carbonic acid of the air, enables the oxygen and azote to act on each other more effectually.

IV.—Experiments on the Absorption of Vapours by Liquids—1828.

From "Edin. Journ. of Science," xvi., 1828, pp. 326-335 ("Schweigger Journ.," liii. (Jahrb. xxiii.), 1828, pp. 249-264).

Saturated solution of chloride of sodium absorbs water in a position where water evaporates, and where the crystals do not deliquesce, at 57° F., 14° C.

Saturated solution of muriate of ammonia and sulphate of magnesia.

Water lost 23 grains. A solution of chloride of sodium, 1 in 4 of water, gained 39 grains. Carbonate of potash, 1 in 4 of

water, gained 6·5. Table of gain of water in six days, and in fourteen days in 10 solutions of salts. Not only deliquescent, but even efflorescent salts, absorb water when in solution, saturated solutions being used, except in the case of carbonate of potash and chloride of calcium.

All saline solutions just as readily inhale as exhale vapours, according to the atmosphere. Column of boiling points. Index of the *in*vaporating powers of the solutions. Liquids *in*vaporate when they take in vapour, and evaporate when they give it out. Gain in five days with chloride of sodium. Loss with sea water.

Examples of solutions which boil at the same point. Absorption of water by muriatic acid, at temperature not above 55° (13° C.) giving out acid and absorbing vapour till the strength is 1·0960.

Sulphuric acid absorbs the vapour of alcohol.

Absorption of alcohol vapour by camphor.

Absorption of carbonate of ammonia. Passage of dry subcarbonate into water.

V.—On the Influence of Air in determining the Crystallization of Saline Solutions—1828.

From "Edin. Roy. Soc. Trans.," xi., 1831, pp. 114-118, Author's Reprint ("Phil. Mag.," iv., 1828, pp. 215-218; "Sillimann Journ.," xvii., 1830, pp. 373-374).

Various opinions. Solutions of Glauber's salts might be kept in tubes inverted over mercury in a trough without crystallizing, if the mercury were heated first, and the whole allowed to cool gradually.

Sometimes solutions did not crystallize by introducing a bubble of air, at temperature not exceeding 150° or 170°F.; in all successful cases crystallization commenced around the bubble of air. Effect may be by absorbing air, the smallest increase causing a change in saturated solutions. The most absorbable gases had the greatest effect.

Ammonia and sulphurous acid act vigorously. Hydrogen, less influential than common air. Minute quantities of foreign liquids, soluble in water, act well. The solution does not expand as water does in freezing. Expansion, temporary, caused by rise of temperature of 20°—30°F. (11°—17°C.).

VI.—A Short Account of Experimental Researches on the Diffusion of Gases through each other, and their Separation by Mechanical Means—1828.

From "Quart. Journ. of Science," ii., 1829, pp. 74-83 ("Poggend. Annal.," xvii., 1829, pp. 341-347; "Schweigger Journ.," lvii. (Jahrb. xxvii.), 1829, pp. 215-227).

Law that gases diffuse, developed by Dalton. Berthollet's results. Diffusion of the different gases into atmospheric air.

Evident that the diffusion of gases is inversely as some function of their density—apparently the square root. Diffusion of mixed gases into atmospheric air.

Of mixed gases, the more diffusive gas leaves the receiver in greater proportion than in solitary diffusion, and the less diffusive in less proportion than in its solitary diffusion.

By taking advantage of diffusion a light gas may be eliminated from others by a species of rectification—so of a denser gas by a converse method.

Diffusion of gases into other atmospheres than common air. Examples—hydrogen and olefiant gas, etc.

§5. Concentration of alcohol by spontaneous evaporation of water. It is conceivable that imperceptible pores or orifices of excessive minuteness may be altogether impassable (by diffusion) by gases of low diffusive power, that is, by dense gases, and passable only by gases of a certain diffusive energy.

VII.—Observations on the Oxidation of Phosphorus—1829.

From "Quart. Journ. of Science," ii., 1829, pp. 83-88 ("Poggend. Annal.," xvii., 1829, pp. 375-380; "Schweigger Journ.," lvii. (Jahrb. xxvii.), 1829, pp. 230-240).

Some curious properties of phosphorus mentioned. The presence of a minute quantity of certain gases and vapours entirely prevents the usual action of phosphorus upon the oxygen of common air.

$\frac{1}{400}$ of olefiant gas in common air, in July and August, prevented the smallest oxidation over water. With $\frac{1}{20}$ of olefiant gas in three months the phosphorus never became luminous. Essential oils prevent luminosity, so also 4 per cent. of chlorine in the surrounding medium, also 20 of sulphuretted hydrogen. Alcohol also at about 80°. Not so vapours from camphor, sulphur, iodine,

benzoic acid, carbonate of ammonia, iodide of carbon, at 67°. Muriatic acid increases, nitric acid diminishes it. Phosphorus therefore cannot take oxygen from mixtures of olefiant gas.

In 1 of air and 1 of olefiant gas, luminosity begins at 200° F; 3 of air and 2 of ether vapour, luminosity begins at 215°; 111 of air to 1 of naphtha, at 170°; 166 of air and 1 of vapour of turpentine, at 186°. Luminous in air, with 50 per cent. olefiant gas under pressure of half-an-inch of mercury. Table of luminosity at different pressures and proportions.

Potassium oxidation retarded by vapour of ether or olefiant gas. Perhaps allied to the property olefiant gas has of preventing explosion of hydrogen and oxygen.

VIII.—Notice of the Singular Inflation of a Bladder—1829.

From "Quart. Journ. of Science," ii., 1829, pp. 88, 89 ("Schweigger Journ.," lvii. (Jahrb. xxvii.), 1829, pp. 227-229).

A bladder filled with coal gas became inflated in carbonic acid gas standing over water.

The outer portion of the bladder would bé moist and absorb carbonic acid. The water would pass the bladder, and the carbonic acid would evaporate within it, as nothing, but the presence of carbonic acid within could prevent the disengagement of that gas.

IX.—On the application of Spongy Platinum to Eudiometry—1829.

From "Quart. Journ. of Science," ii., 1829, pp. 354-359 ("Erdm. Journ. Tech. Chem.," viii., 1830, pp. 20-27).

Olefiant gas, which had been found to prevent the oxidation of hydrogen and oxygen, was found to lose this power when sedulously washed with caustic potash. Then the ball with platinum acts in a few minutes, and the heat is so great that some of the olefiant gas is oxidized, and carbonic acid always appears. The same with vapours of naphtha and essential oils. With sulphuretted hydrogen the latter gas only oxidized, and little of the free hydrogen. Sulphurous acid also hinders the oxidation of free hydrogen. The action of these gases is therefore unlike the action of the same gases and vapours in protecting phosphorus from oxidation. The action not influenced by diminishing barometric pressure.

X.—On the Law of the Diffusion of Gases—1838.

From "Phil. Mag.," ii., 1833, pp. 175-190, 269 276, 351-358 ("Poggend. Annal," xxviii., 1833, pp. 331-358; "Edin. Roy. Soc. Trans.," xii., 1834, pp. 222-258).

The object is to establish with numerical exactness the following law of the diffusion of gases. "The diffusion or spontaneous intermixture of two gases in contact is effected by an interchange of position of indefinitely minute volumes of the gases, which volumes are not necessarily of equal magnitude, being in the case of each gas, inversely proportional to the square root of the density of that gas."

The volumes may be called equivalent volumes of diffusion:—air, 1; hydrogen, 3·7947; carburetted hydrogen, 1·3414; water vapour, 1·2649; nitrogen, 1·0140; oxygen, 0·9487; carbonic acid, 0·8091; chlorine, 0·6325. Gases being separated by a screen, with apertures of insensible magnitude, the interchange of "equivalent volumes of diffusion" is effected by a force of the highest intensity: if the gases are of unequal density, there is an accumulation on the side of the heavy gas. The process of exchange continues till both sides are equalized. Doebereiner's explanation, viz., the capillary action of the fissure in the case of a broken jar, is improbable; hydrogen is condensed and absorbed by porous bodies, according to Saussure, with greatest difficulty, and we have no reason to suppose that its particles are smaller than those of other gases. When hydrogen escapes air always enters.

Better than broken jars are Wedgewood stoneware tubes unglazed. But these are superseded by gypsum.

A diffusion-tube—a glass tube open at one end, and with a plug of gypsum at the other, was filled with hydrogen, over mercury, when that liquid rose 2 inches in three minutes; with water it is striking, the rise in a tube 14 inches long is 6 to 8 inches in as many minutes.

Amount of five gases absorbed in the pores of the stucco—oxygen hydrogen, nitrogen, carbonic oxide, olefiant gas, and coal gas, not in sensible proportions. Vacuity of the stucco one-third of the volume. Experiments on the diffusion of hydrogen in the air. Wet and parched plugs of stucco. Some anomaly in the action of hydrogen.

The more compact and dense plugs are the best. When the plug is lose, the return of air is notably diminished in the case of

hydrogen. Passage of gases into vacuum in time through a stucco plug, not in direct proportion to pressure.

Tables of the times. The kind of gas in the receiver did not alter the velocity with which hydrogen entered under a certain pressure.

Dry sound corks answer well as a substitute for stucco-plugs. This passage of hydrogen is against Dalton's opinion that one gas is vacuum to another. Diffusion of carbonic acid. The gas confined over a solution of common salt.

Chlorine, Sulphurous acid, protoxide of nitrogen, Cyanogen.

Muriatic acid, ammoniacal gas, sulphuretted hydrogen.

Oxygen, Nitrogen, olefiant gases, carbonic oxide.

Carburetted hydrogen of marshes. General table. In the volumes of oxygen, nitrogen, and carbonic oxide, theory and experiment agree as closely as could be desired.

Density of any gas diffused into air, both being in the same state as to aqueous vapour, is obtained by the formula $D = (\frac{A}{G})^2$ where G is the volume of the gas diffused, and A the returned air. It is possible to come within 100th part of the specific gravity by operating on a cubic inch of gas.

Nitrogen and carbonic oxide diffuse without any contraction on either side. Same density. Inequality of density not essential requisite in diffusion. Plugs not used for some days did not diffuse. Hydrogen opened a passage in a few minutes, and they went on as before. Heat also restored the action; dust the cause of stoppage. Evaporation may be explained on the principle of diffusion.

Mechanism of respiration. Carbonic acid being carried out from the air-cells, oxygen is carried in.

Heavy carbonic acid exchanged for a larger amount of oxygen, and may explain inflation of the minute tubes. To insect respiration most distinctly perceived applicable. Diffusion takes place by interchange of position of indefinitely minute volumes of the gas, not between sensible masses. The law not provided for in the corpuscular philosophy of the day. Supplementary observations on the law of diffusion of gases.

Some gases mix more rapidly than others, still keeping in conformity with the law. This is connected, in the case of hydrogen, with the apparent deviation from the law of diffusion, mentioned p. 53. It is there shown that more hydrogen passes out than the exact quantity proportional to the return air.

XI.—On Phosphuretted Hydrogen—1835.

From "Edin. Roy. Soc. Trans.," xiii., 1835, pp. 88-106 ("Phil. Mag." v., 1834, pp. 401-415; "Erdm. Journ. Prak. Chem.," iii., 1834, pp. 400-416).

Spontaneously inflammable, prepared by heating phosphorous, lime, and water; not spontaneously inflammable when allowed to stand over water 24 hours, or when made by heating hydrated phosphorous acid. The peculiarity attributable to something adventitious. Not free phosphorus presumably, because that is less accendible than the hydrogen compound. Loss of accendibility over water caused by rise of oxygen from air in the water. Free hydrogen unexpectedly rendered the gas self-accendible, but not if quite pure.

Caused by nitrous acid vapour.

Spontaniety destroyed by charcoal, caustic potash,—phosphorous acid, strong arsenic acid, essential oils, and most hydrocarburets, alcohol, olefiant gas slowly and potassium.

Spontaneous action restored by small quantities of nitrous acid, not by a large amount, between 1 and 10 to 10,000 of phosphuretted hydrogen.

Nitric oxide acts only when nitrous acid is in it.

In the reaction there is a spontaneous formation of compounds of phosphorus and oxygen.

The gas obtained by ordinary processes probably owes its peculiarity to a minute trace of such a compound, analogous to nitrous acid.

XII.—On a New Property of Gases—1845.

From Report of Brit. Assoc. for the Advancement of Science, 1845 (Part ii.), p. 28.

The passage of gases into a vacuum. Speed of effusion. Proposal to find the density by speed of effusion. Passage of gases through porous bodies, called transpiration. Air more rapid than oxygen. Carbonic acid more rapid also, and under low pressure more rapid than air.

XIII.—On the Composition of the Fire-damp of the Newcastle Coal Mines—1845.

From Memoirs of Chem. Society, iii., 1845-48, pp. 7-10.

Only carburetted hydrogen, nitrogen, and oxygen found. The power of resisting oxidation remarkable in light carburetted

hydrogen; cause of its being found in coal mines. Resists the action of platinum black, but permits other gases to be oxidated.

XIV.—On the Motion of Gases. Part I.—1846.

From Phil. Trans. iv., 1846, pp. 573-632; ii., 1849, pp. 349-362.

Necessary to keep apart the phenomena of the passage of a gas through a small aperture in a thin plate, and its passage through a tube of sensible length. Rate of discharge independent of the material of the tube.

Rate of discharge of gases by tubes has no uniform relation to the density of the gases. Passage of gas through a thin plate. Effusion tube. Transpiration.

Part 1.—Effusion of Gases.—Effusion of hydrogen into a vacuum by a glass jet.

Effusion of oxygen and nitrogen; of carbonic oxide; of carburetted hydrogen of marsh gas.

Effusion of carbonic acid and nitrous oxide; of olefiant gas.

Effusion into a vacuum by a perforated brass plate A, with results. Different gases pass through minute apertures into a vacuum in times which are as the square roots of their specific gravities. For a proper effect the plate ought to have no sensible thickness.

Tubularity of the opening quickens the passage of carbonic acid and nitrous oxide in reference to air, they being more transpirable and less diffusive than air. Effusion of nitrogen and oxygen, and of mixtures of these gases under different pressures, by a second perforated brass tube B.

Table of effusion of air, nitrogen, oxygen, and mixture.

Effusion of air, carbonic acid, oxygen, and mixture, at different pressures, by plate B.

Effusion of carbonic acid, air, and of mixtures of carbonic acid and air, at different pressures, by plate B.

Effusion of mixtures containing hydrogen.

Effusion into a sustained vacuum by platinum plate E.

Effusion of air of different elasticities or densities by brass plate B. The effusion time of air of two atmospheres falls below that of air of one atmosphere.

Effusion of air of different temperatures by plate F.

Effusive time of air of different temperatures is proportional to the square root of its density at each temperature. Moist air, great effect in opening fissures.

Part 2.—Transpiration of Gases.—Transpiration of air of different densities or elasticities by a glass capillary tube E.

For equal volumes of air of different densities the times of transpiration are inversely as the densities. Transpiration of air of different temperatures.

Preliminary experiments on the transpiration of different gases by capillary A.

Preliminary experiments on the transpiration of different gases by capillary B.

Preliminary experiments on the transpiration of different gases by capillary C, 1 inch long.

Preliminary experiments on the transpiration of different gases by capillary C, 2 inches long.

Preliminary experiments on the transpiration of different gases by capillary C, 4 inches long.

Transpiration by capillary H, 22 feet long, of glass, into vessels of different sizes.

Transpiration by capillary H with cupped ends. By cupping the end of ingress the passage of air became slender in the proportion of 509 to 496; cupping the egress caused no further change, pressure being between 28·5 and 23·5 inches.

Transpiration of different gases by a capillary tube of copper; tube, 11 feet 8 inches; diameter, 0·0114 inch.

Transpiration of different gases by a glass capillary E. This was 20 feet long and 0·0187 inch diameter.

All these tubes gave the same co-efficient of transpiration to each gas.

A certain length of tube most favourable.

A certain interference supposed to depend on friction.

Theory of transpirability, that it is a kind of elasticity, depending upon the absolute quantity of heat, latent as well as sensible, and more immediately connected with specific heat than any other property of gases.

Transpiration of olefiant gas.

Transpiration of nitrous oxide.

Transpiration of sulphuretted hydrogen.

Conclusions drawn from Tables XLII. to LV.

Tables of the observed transpiration of gaseous mixtures.

XV.—On the Motion of Gases. Part II.—1849.

From Phil. Trans., 1849, pp. 349-392.

The velocities of gases attain a particular ratio with a certain length of tube and resistance. After attaining this the passage of of gases become slower.

Transpiration velocity of hydrogen double that of nitrogen; that of carbonic oxide and nitrogen the same. Velocity of nitrogen and oxygen inverse to the densities, equal weights and not equal volumes being transpired.

Points demanding attention. Capillary tubes for transpiration.

Transpiration by capillary H reduced to 237·875 inches. Transpiration of equal volumes by capillary H of different lengths.

Transpiration of all gases does not become normal for the same length of tube or resistance.

Use of a thermometer tube of fine flat bore, capillary K, 52½ inches.

K shortened to 39·375 inches.

„	26·25	„
„	13·125	„
„	8·75	„
„	6·4375	„
„	4·3125	„

Use of capillary M 52½ inches thermometer, tube as above, bore cylindrical. K and M have 50 times the resistance of E and H capillaries of extreme resistance recommended.

Capillary P, a compound one, formed of 30 capillary tubes each 4 inches in length, in a sheaf 400 times the resistance of K and M. Gases compressed instead of being drawn into a vacuum.

Results obtained by this sheaf of capillaries of extreme resistance the most uniform of all.

In carbonic acid the carbon gives velocity to the oxygen, showing the important chemical bearing of transpirability.

Transpiration of various gases and vapours:—

Protocarburetted hydrogen.

Olefiant gas.

Ammonia.

Cyanogen. Hydrocyanic acid.

Hydrosulphuric acid.

Bisulphide of carbon. Sulphurous acid.

Sulphuric acid.
Chlorine.
Bromine, Hydrochloric acid.
Ether.
Methylic ether.
Chloride of methyl.
Water.
Alcohol, naphtha and coal gas.
Transpiration of air of different densities or elasticities.
Transpiration of air and other gases at different temperatures.
Transpiration of equal volumes at different temperatures.
Transpiration of air under pressure (into air) at different temperatures.
General results of the inquiry.

XVI.—On the Molecular Mobility of Gases—1863.

From Phil. Trans., 1863, pp. 385-405 ("Chemical News," viii., 1863, pp. 79-81; "Paris Comptes Rendus," lvii., 1863, pp. 181-192; "Pharmaceut. Journ.," v., 1864, pp. 166-171; "Poggendorf Annal., cxx., 1863, pp. 415-425).

The passage of gases under pressure through a thin porous plate or septum.

Description of the graphite diffusiometer. Pores so small that molecules only can pass, not gases in mass. Sole motive agency, the intestine movement of molecules. The hypothesis of the movement of gaseous particles, by Bernoulli, revived in recent times by J. Herapath.

The passage of gas through a graphite plate agrees with the times of diffusion, not of transpiration.

Diffusion tube with pressure of 100 mms. of mercury.

Diffusion tube described to obtain a torricellian vacuum.

Movement through graphite and stucco plates.

Stucco under pressure gives mixed diffusion and capillary transpiration. Movement through biscuit ware.

Passage through graphite closely proportional to pressure. Passage of a mixture of air and hydrogen.

Time neither diffusion nor transpiration. Gas altered in composition. Each gas impelled by its own molecular force. Separation is a consequence of the movement being molecular.

Permeation through the graphite plate into a vacuum, and the diffusion into a gaseous atmosphere due to the same inherent mobility of the gaseous molecule. The diffusive mobility is a property of matter fundamental in its nature.

The physical basis is the molecular mobility.

Diffusion of mixed gases into a vacuum with partial separation —Atmolysis.

Oxygen and hydrogen, amount of separation in proportion to the pressure.

Oxygen and nitrogen, separation of.

All porous masses will have some effect in separating mixed gases. The tube atmolyser—a clay tube within a glass or metal one to increase rapidity.

Separation of oxygen from hydrogen and nitrogen.

Interdiffusion of gases—double diffusion. Remarks on Bunsen's results.

Interdiffusion without an intervening septum.

A portion of carbonic acid travelled at an average rate of 73 millimetres per minute, of hydrogen a third of a metre in one minute.

XVII.—On the Absorption and Dialytic Separation of Gases by Colloid Septa.

From "Phil. Trans.," 1866, pp. 399-439.

Part I.—Action of a Septum of Caoutchouc—Dr. Mitchell's experiments.

Important to remember the complete suspension of the gaseous function during the transit through the colloid membrane.

Passage of gases through caoutchouc.

The relation not that of diffusion. The first absorption of the gas by the rubber must depend on a kind of chemical affinity.

A film of caoutchouc has no porosity, and resembles a film of liquid in its relation to gases.

Liquids and Colloids have an unbroken texture, and afford no opportunity for gaseous diffusion.

Penetration of varnished silk.

Absorption of gases by a block of caoutchouc. Dialytic separation of oxygen from atmospheric air (1) by means of other gases; (2) by means of a vacuum.

Dialytic action of caoutchouc in various forms.

Dialytic action of silk cloth, varnished with caoutchouc on one side, slightly vulcanized.

Percolation of air through gutta-percha and other septa.

Part II.—Action of Metallic Septa at a Red Heat.

Platinum porosity when heated. Deville.

Platinum tube 1·1 millm. in thickness. Not permeable to hydrogen till of a red heat, and then more permeable than caoutchouc. Is the difference of temperature the cause?

Heated platinum, with oxygen and nitrogen, not sensibly permeable. Carbonic acid penetration incalculably small.

Heated platinum, with chlorine, not sensibly penetrating. Hydrochloric acid do., vapour of water do., ammonia do. Carbonic oxide, marsh gas, and olefiant gas not penetrating.

Hydrosulphuric acid not penetrating. Table of above results.

Absorption and detention of hydrogen by platinum.

A new property in platinum to absorb and retain hydrogen at a red heat, occlusion of hydrogen 3·79 vols. for wrought platinum.

Palladium.

Occlusion of hydrogen 643·3 vols. Hydrogen absorbed at natural temperature in vacuo.

Action of the occluded hydrogen on salts.

Palladium, its absorptive power for liquids. Alloy of silver and palladium.

Conclusions regarding the absorption by palladium. Hydrogen taken up as a volatile liquid.

Separation of pure hydrogen from a gaseous mixture. Passage of ether through palladium.

Speculations on the pores of metals, and the excess obtained in the diffusive co-efficient of hydrogen, caused by a small amount of liquefaction. Osmium-iridium, no absorbent power. This is consistent with its crystalline character.

Copper—occludes 0·306 vol. hydrogen. Gold—occlusion of nitrogen, oxygen, carbonic acid and oxide, hydrogen.

Silver—occlusion of above gases.

Iron—penetration by hydrogen.

By carbonic oxide 4·15 vols. Acieration and carbonic oxide.

XVIII.—*On the occlusion of Hydrogen by Meteoric Iron—1867.*

From Proceedings of the Royal Society, vol. xv., p. 502, May 16, 1867; "Comptes Rendus," May 27, 1867, vol. lxiv., p. 1067; "Poggendorf's Annal.," vol. cxxxi. (1867), p. 151.

That of Lenarto yielded 2·85 vols. of gas, with 86 per cent. of hydrogen.

XIX.—*On the occlusion of Hydrogen Gas by Metals—1868.*

From Proceedings of the Royal Society, June 11, 1868, vol. xvi., p. 422; ("Comptes Rendus," May 25, 1868, vol. lxvi., p. 1014; "Archives des Sciences," June 1868, vol. xxxii., p. 148; "Annales de Chemie et de Physique (4)," vol. xiv., p. 315; "Poggendorf's Annal," vol. cxxxiv., 1868, p. 321; "Philosophical Magazine (4)," vol. xxxvi., p. 63.

A thin plate of palladium in contact with zinc which is giving off hydrogen in sulphuric acid occludes that gas. Still more, when the plate is the negative electrode to a Bunsen battery of six cells. This gas is not given out in a vacuum, it is taken out by heat, or by reversing the position of the palladium in the cell, and evolving oxygen on the surface.

Palladium charged with hydrogen apt to heat spontaneously in the air.

Platinum charged with hydrogen by voltaic action. Soft iron occluded 0·57 vols. hydrogen.

Explanation by the electro-chemical theory.

Precipitated palladium occluding 982·14 vols. of hydrogen.

Penetration by hydrogen and carbonic acid. Liquid diffusion explains the passage of hydrogen through a soft colloid metal.

"Solution affinity" of metals confined to hydrogen and carbonic oxide.

XX.—*On the Relation of Hydrogen to Palladium, and on Hydrogenium—1869.*

From Proceedings of the Royal Society, vol. xvii., pp. 212, 500, Jan. 14, 1869; "Comptes Rendus," Jan. 18 and June 28, 1869, vol. lxviii., pp. 101, 1511; "Annales de Chemie et de Physique (4)," vol. xvi., p. 188; "Chemical News," vol. xix., p. 478; "Berichte der deutschen chemischen Gesellschaft (No. 2)," 1869; "Annalen der Chemie," vol. clii., p. 168; "Philosophical Magazine," December 1869; "Poggendorf's Annalen der Physik," vol. cxxxviii. (1869), p. 49.

Properties of occluded hydrogen, which if metallic would have to be called hydrogenium. Palladium charged with hydrogen is

lowered in density. Emits bubbles when in water, so that the density is obtained best by measurement and calculation.

A piece of palladium wire 609·144 millims. long, charged with 936 vols. of hydrogen, was increased to 618·932 millims., showing increase of 9·778 millims. (or 23·982 inches gained 0·385 in.), increase in length 100 to 101·605, and in cubic capacity from 100 to 104·908.

Alloy:—Palladium 95·32.
Hydrogenium 4·68.

100· giving density of hydrogenium 1·708,

The palladium wire lost when heated 9·7 millims. below original length: gravity less: length only was contracted. Mobility of metallic particles. Combustion of the wire. Another experiment, hydrogenium 1·898 specific gravity, and a third 1·977.

Further trials, highest number 2·055, retraction of the wire continues in four experiments.

Loses its power to occlude hydrogen, and after 6 times only 320 and 330·5 volumes. Power restored partly by heat, and wholly by extracting the hydrogen by electrolysis in an acid fluid. Tenacity of palladium being 100, that of palladium and hydrogen was 81·29 electrical conductivity, copper 100, palladium 8·10, palladium and hydrogen 5·99.

Hydrogenium, a magnetic metal. Slight absorption of hydrogen at a high temperature. Speed of movement through palladium 1 millim. in thickness is 4 millims. per minute.

Alloy contains about 20 volumes of palladium, and 1 of hydrogenium. An approach to equivalents. Summary.

XXI.—*Speculative Ideas concerning the Constitution of Matter —1864.*

From the "Philosophical Magazine" for February, 1864.

It is conceivable that the various kinds of matter may possess one and the same ultimate or atomic molecule in different conditions of movement.

Ponderable matter and a common atom. The atom is not at rest. Motion due to primordial impulse. This gives rise to volume. The more rapid the movement the greater the space occupied by atoms. Matter of different density forms different substances. This not applied to known gases which are composed

of molecules or groups of atoms. There may be infinite repetitions of such steps. Molecular volumes of different elementary substances have the same relation to each other as the subordinate atomic volumes of the same substances.

Volumes uniting retain a portion of the original movement and volume. This is chemical combination. The same result attained by hypothesis of a fluid medium caused to undulate. A special rate of vibration or pulsation imparted to a portion of the fluid medium. No incompatibility between the liquid, solid, and gaseous states. Possibility of something like an undeveloped condition of matter connecting two states.

Molecular mobility has an obvious bearing on the communication of heat to gases. The impact of the gaseous molecule, when more rapid, produces more frequent contact. A hot object in hydrogen is touched 3·8 times more frequently than in air. Dalton ascribes this to mobility. Hydrogen in an air engine favours the alternate heating and cooling of a confined volume of gas.

SALTS AND SOLUTIONS.

I.—On Exceptions to the Law that Salts are more Soluble in Hot than in Cold Water, with a new instance—1827.

From "Philosophical Magazine and Annals of Philosophy," ii., 1827, pp. 20-26.

Phosphate of magnesia prepared by precipitation.

Efflorescent. Solution cloudy at (120°F.) about 50°C.

Precipitate like anhydrous phosphate.

774 parts water dissolve 1 at 7°·2, and
1151 do. do. 1 at 100°.

Time required to dissolve it.

Mere continuance of heat did not increase the precipitate. A solution once precipitated by heat did not precipitate more except by greater heat. Efflorescence in hydrates shows a weak affinity for water.

As all the hydrates of salts lose water by heat, there is a point at which every salt diminishes in solubility.

Some substances insoluble in water whilst the hydrates are soluble, such as silica.

II.—An Account of the Formation of Alcoates. Definite Compounds of Salts and Alcohol analogous to the Hydrates —1831.

From "Edin. Roy. Soc. Trans.," xi., 1831, pp. 175-193 ("Phil. Mag.," iv., 1828, pp. 265-272, 331-336; "Journal de Pharm.," xv., 1829, pp. 105-124; "Poggendorf Annal.," xv., 1829, pp. 150-153; "Quart. Journ. of Science," ii., 1828, pp. 442, 443; "Schweigger Journ.," lvi. (Jahrbuch xxvi.), 1829, pp. 180-203).

Mode of concentrating alcohol by quicklime. Quicklime absorbs a small quantity of alcohol vapour.

Sulphuric acid absorbs the vapour of absolute alcohol, as of water.

Chloride of calcium absorbs it. Compound described.

Alcoate of nitrate of magnesia.

Do. of lime.

Do. of protochloride of manganese.

Do. of chloride of zinc; chlorides of magnesium and iron.

Dent-absorption of dent-oxide of azote by protochloride of iron and alcohol more than by the salt alone.

Absorption by the iron salt may show a tendency to deliquesce in an atmosphere of that gas, the retaining power being equal to the absorbing power.

III.—Researches on Arseniates, Phosphates, and Modifications of Phosphoric Acid.

From "Philosophical Transactions," 1833, pp. 253-284.

1.—Subsalts.—Description of subarseniate and subphosphate of soda.

Explanatory hypothesis that phosphoric acid is disposed to unite with three atoms of base, common phosphate of soda being phosphate of soda and water. For the water another base may be substituted, as an atom of soda in the subphosphate, or an atom of silver in the corresponding salt. Pyrophosphate produced by heating phosphate, not by subphosphate, as it leaves an excess of base. Phosphoric acid by burning phosphorus.

Water in the crystals of subarseniate of soda, probably 24 atoms differing from the neutral arseniate by an atom of soda substituted for water.

Subphosphate dried, heated, fused with protoxide of lead. Calcined with exposure to carbonic acid.

Subsesquiphosphate formed.

Subphosphates and subarseniate of potash.

Barytes, lime, and lead salts.

2. Neutral Phosphates and Pyrophosphates.—Clark on the action of heat on the phosphate of soda, and removal of the last atom of water.

Phosphate of soda has three atoms base—two soda, one water; added to earthy and metallic salts, gives precipitates, with three atoms base; one may be water, the basic function of which is essential to the phosphate of soda. The pyrophosphate has two atoms base, and gives accordingly bibasic precipitates. Unusual appearance of the crystals after long boiling of the solution.

3. Of the Superphosphates. (1st) Of the biphosphate. Remarkable body. Its dimorphism. Crystals contain four atoms of water, and lose two at 212° F. (100° C.), and no more till 375° F. (191° C.)

Two atoms essential to the salt—one atom soda, two water, and a double atom of phosphoric acid—these three atoms replaceable by three of oxide of silver. Second variety of bipyrophosphate of soda. The biphosphate heated to 400° F. (204° C.) rapidly semifuses, and one atom of water comes off in ebullition.

Salt, still soluble, but altered. Precipitates silver white, and with two atoms to a double atom of the acid, pyrophosphate of silver.

Third variety of the biphosphate of soda. The above biphosphate heated between 400° and 470° F. (204° and 243 C.) for several days. Small part insoluble nearly, see p. 341. Solution exactly neutral. Probable composition.

Fourth or insoluble variety of biphosphate of soda. If sufficient heating were possible, water would probably be incapable of acting on it. Reasons for this. Fifth variety of biphosphate of soda. The preceding insoluble variety heated to low redness.

Description of its properties. Metaphosphate.—Not crystallized, changed. The acid coagulates albumen. The glacial acid was supposed to be pyrophosphoric. The hydrated salt retains one atom water heated to 400° F. (204° C.), becoming bipyrophosphate The anhydrous fused metaphosphate is not changed by heating for several days, change effected by water; dried sharply, or with sufficient alkali, becomes common sub-phosphate.

Metaphosphate of Barytes.—Insoluble even by washing in hot water, but on long boiling is decomposed and dissolved, biphosphate of barytes being in the solution.

4. On the Modifications of Phosphoric Acid.—Acid in common phosphate of soda has three atoms of base to the double atom of acid. Does not effect albumen. Other modifications pass into it in solution, after some days in water or boiling, on fusion with three proportions of fixed base. Pyrophosphoric acid of the fused phosphate forms salts with two atoms base. Does not disturb albumen, or make a precipitate in muriate of barytes.

The metaphosphoric acid disposed to form salts, with one atom of base to the double atom of acid. Made by heating the other modifications *per se*, or with only one atom of certain fixed bases. These three acids, even when free, have still their usual proportion of base, and that base is water, or they are a terphosphate, a biphosphate, and a phosphate of water.

Table of oxygen in the salts. Loss of water by heating phosphoric acid. Possible hydrates of the acid. Binarseniate of soda does not undergo the same changes as biphosphate.

IV.—On Hydrated Salts and Metallic Oxides: with Observations on the Doctrine of Isomerism—1834.

From "Brit. Assoc. Report," 1834, pp. 579-582 ("Liebig Annal.," xii., 1834, pp. 1-12; "Poggend. Annal.," xxxii., 1834, pp. 33-75.)

Certain salts mentioned with five or seven atoms of water retain one in more intimate union than the others.

Sulphate of zinc loses 6 atoms at 65° F. (18·2° C.), and retains one up to 410° F. (210° C.) This salt may be viewed as a sulphate of zinc and water, with 6 atoms of water of crystallization. This last atom discharges a basic function explaining the disposition of the salt to form double sulphates. Sulphate of potash may take the place of this water, and form the double sulphate of zinc and potash. Sulphate of lime, peculiarity.

Protochlorides and cyanides. Tin. Two oxides. Different hydrates. Various peroxides and some salts obtained as débris of hydrates by heating. Incandescent on heating to redness. Isomerism, which has been proposed to explain the change of character in bodies of the same composition, may often be explained by certain differences in composition when carefully

examined, *ex.gr.*,—(1) The water of the phosphoric acids; (2) Some bodies are mere débris of chemical compounds; (3) The proximate constitution may be very different when the ultimate is the same. No evidence of cyanogen in fulminic acid. Tartaric acid and racemic probably have as little relation to each other as any two vegetable acids which could be named, certainly contain different radicals. (4) A minute trace of adventitious matter may affect a body. See phosphuretted hydrogen.

V.—On Water as a Constituent of Salts—1836.

From "Edin. Roy. Soc. Trans.," xiii., 1836, pp. 297-314 ("Phil. Mag.," vi., 1835. pp. 327-334, 417-424; "Annal. de Chimie," lxiii., 1836, pp. 45-64; "Erdm. Journ. Prak. Chem.," v., 1835, pp. 90-109, xv., 1838, pp. 437-439; "Liebig Annal.," xx., 1836, pp. 141-149; "Poggend. Annal.," xxxviii., 1836, pp. 123-142).

Water in salts of ammonia. Water of crystallization, feeble affinity. Water in the caustic alkalies has the function of an acid.

The inseparable water of acids, as of sulphuric acid, has been held to be basic, and that acid to be a sulphate of water and bisulphate or bitartrate of potash a double salt. Development of this view in the memoir on the phosphates. Now finds water to exist in a different state, replaceable by salt. The tendency of phosphate of soda to unite with more soda was traced to the existence of basic water in the former. The question arose, Does an analogous provision exist in such salts as form double salts?

In the sulphates of magnesia, zinc, iron, manganese, copper, nickel, and cobalt, an atom of water seems essential. In sulphate of zinc and potash one of the seven atoms of water in the first salt is replaced by sulphate of potash, and the six atoms of water remain as water of crystallization.

Supersulphates, double salts. Second atom of water in sulphuric acid replaced by sulphate of potash, but the first replaceable only by a true base. The sulphuric acid hydrate, therefore, has an atom of basic and an atom of saline water, just as the hydrous sulphate of zinc is a sulphate of zinc with saline water. No supersulphates of magnesia, &c., are analogous in constitution, and do not tend to combine. Sulphate of water with saline water. The primary sulphate. Specific gravity, 1·78. The dilute acid may be concentrated at a temperature not exceeding 380°F. (193°C.),

without loss of acid, the water reduced to two atoms. At 400° or 410° F. (264°—210 C.) this hydrate begins to be decomposed.

Sulphate of water and sulphate of potash. Bisulphate of potash, without water or crystallization.

Sulphate of potash, sulphate of soda. Of the ten atoms of water in crystals of sulphate of soda, none essential to its constitution, crystallizes anhydrous from a hot solution.

Sulphate of Zinc with saline water. Heated above 410°F. (210°C.), loses the last atom of water, but regains it with evolution of heat when moistened. Sulphate of zinc and potash. Retains the six atoms with more force than the sulphate of zinc alone. The sulphate of potash does not neutralize the acidity.

Sulphate of zinc and soda. Not obtained merely by crystallizing together the mixed salts, but from a solution of bisulphate of soda and sulphate of zinc in a day or two.

Sulphate of copper and saline water. Loses its fifth or saline atom above 430° F. (221°C.) Takes it up with evolution of heat. Sulphate of copper and potash. Table of water at different temperatures.

Sulphate of copper and soda.

Sulphate of manganese, with saline water, five atoms of water reduced to one, at 410° F. (210° C.) Table of water at different temperatures. Sulphate of iron with saline water. The saline atom of water retained to the temperature of 535° F. (279° C.)

Hydrated sulphate of lime. A sulphate with one atom of water obtained by heating the hydrate over sulphuric acid in vacuo at 212°F. (100° C.) The salt can be made anhydrous at 300°F. (149° C.) Table of water at different temperatures. Monohydrate does not adhere like stucco. This power retained to 270°F. (132° C.) The heated sulphate—the débris of the hydrate, not to be confounded with anhydrate.

Anhydrous gypsum may be written with a – or minus after it to show that something is wanting. Anhydrate requires no – as it takes up no water. Sulphuric acid and other salts may be equally represented. This view of the constitution of sulphates must not be hastily applied to other classes of salts, as each has its own peculiarities to be studied.

VI.—On the Water of Crystallization of Soda-Alum—1836.

From "Phil. Mag.," ix., 1836, pp. 26-32 ("Liebig Annalen," xxiii., 1837, pp. 269, 270; "Poggend. Annal.," xxxix., 1836, pp. 582-585).

Of soda-alum. This alum, like potash alum, has octohedral crystals, but is said to contain two atoms more water than the latter. No proof of isomorphism of soda and potash, but rather that soda, plus two atoms water, is isomorphous with potash.

Mode of preparation. Efflorescent. Contains, like potash alum, 24 atoms of water.

VII.—Inquiry respecting the Constitution of Salts, Oxalates, Nitrates, Phosphates, Sulphates, and Chlorides—1837.

From "Phil. Trans.," 1837, pp. 47-74 ("Liebig Annal.," xxix., 1839, pp. 1-35.)

From the paper on water in salts would be inferred an analogy between any hydrated acid and its magnesium salt. So the oxalate and nitrate of water resemble the oxalate and nitrate of magnesia. In certain subsalts of the magnesium class of oxides the metallic oxide replaces the crystallization water. As in the case of sulphates, an atom of water seems to be replaced in the oxalates, so as to form double oxalate.

1.—Of the Oxalates.—Oxalate of water, or hydrated oxalic acid. Three atoms of water one basic. The two others may be termed constitutional, and are found in the magnesium oxalates. By drying, two atoms are lost or none.

Oxalate of Zinc.—Retains its two atoms water strongly.

Oxalate of Magnesia.—Retains these two atoms still more strongly.

Oxalates of Iron, Nickel, and Cobalt.—Not obtained pure, as they appear to carry down part of the precipitant. No binoxalate of magnesia.

Oxalate of Lime.—Contains two atoms of water, lost readily. Oxalate of barytes—one atom water, and thus differs from preceding.

Oxalate of Potash.—Crystalizes with one atom of water. Binoxalate of potash contains three atoms. The constitutional water of the neutral oxalate displaced by oxalate of water, which has two atoms.

Quodroxalate of Potash.—The two atoms of preceding salt replaced by two atoms of hydrated oxalic acid. Has seven atoms of water, four of which it loses at 240° F. (116° C.), being the two atoms of water of the two atoms oxalic acid.

Oxalates of Ammonia.—Agree with those of potash. There is also a quadroxalate as well as binoxolate.

Oxalate of soda.—Least soluble of soda salts. Anhydrous. With oxalic acid forms a binoxalate. No quadroxalate. Absence of water probably shows an indifference for further combination.

Binoxalate of soda—three atoms of water. Like the potash, salt loses only two at 300° F. (147° C.)

Double oxalates.—One member of the magnesium class of oxides, namely—copper forms binoxalates with an alkaline salt.

Oxalate of copper and potash.—One form of crystal has two, the other four atoms of water. The second loses two by efflorescence. The oxide of water is substituted for the basic water of the binoxalate.

Oxalate of chromium and potash, with six atoms water.

Oxalate of peroxide of iron and potash.

Oxalate of peroxide of iron and soda.

These three salts occupy the same important position among the oxalates as the alums among the sulphates.

2. Of Nitrates. — (1) Hydrated nitric acid the nitrate of water. This has one atom of water as base, and three held less powerfully.

(2) Nitrate of Copper.—Two crystals. The prisms contain three, the rhomboids six atoms of water, and lose three readily; the other three cannot be expelled without loss of acid.

(3) Subnitrate of Copper.—Thinks the single atom of water to be the base, and the three atoms of oxide of copper in place of the constitutional water of the nitrate of water.

(4) Nitrate and Subnitrate of Bismuth.—The neutral nitrate contains three atoms of water like the nitrate of copper.

(5) Nitrate of Zinc.—Contains six atoms of water which cannot be reduced below three without loss of acid.

(6) Nitrate of Magnesia.—Contains six atoms of water. At heat of melting lead reduced to one atom. This intimate combination of one atom does not indicate a disposition to form a double salt, and is probably the result of a new arrangement of the constituents at a high temperature. No proof of the existence of supernitrates.

3.—Of Phosphates.—Table of phosphoric and salts. Nomenclature—monobasic, bibasic, and tribasic.

(1) Tribasic phosphate of soda, ammonia, and water.—The name expresses the view of the constitution of the salts.

(2) Tribasic phosphates containing oxides of the magnesium class. —Tribasic phosphate of zinc and water has two atoms of water difficult to expel, besides one basic. Tribasic arseniate of magnesia and water has fifteen atoms water of which three, one being basic, are retained at 212° F. (100° C.)

(3) Tribasic phosphate of magnesia and water—has fifteen atoms of water reduced at 212° F. (100° C.), to seven atoms one of which is basic.

(4) Tribasic phosphate of magnesia and ammonia.—This not a double phosphate, but formed from the tribasic phosphate of magnesia and water by the substitution of oxide of ammonia for the basic water of that salt.

4. Sulphates. (Chromates.) See former paper.

As to the suggestion that bisulphate of potash is a double sulphate of water and potash, and therefore nearly neutral in composition, if all bisalts are neutral in composition, what explains the condition of the bichromate? The vapour of anhydrous sulphuric acid is absorbed by sulphate of potash and chloride of potassium without decomposition. Chromic acid forms analogous compounds; with neutral chromate, it forms the red chromate, and with chloride of potassium Peligot's salts analogous to, but more permanent than Rose's sulphates. The red chromate may then belong to a new order of combination.

Sulphates hold water with remarkable force. That of copper retains its four atoms at 212° F. Alum an alkaline sulphate with alumina attached.

5. Chlorides.—Hydracids have a weak affinity for water.

The law seems to be that chlorides of the magnesian class have two atoms of water pretty strongly attached. Some have two or four more, advancing by two's.

(1) Chloride of copper, two atoms of water.

(2) Chloride of manganese, four atoms water.

(3) Protochloride of iron, four atoms water.

(4) Chloride of magnesium, six atoms water.

(5) Chloride of calcium, six atoms water, reduced in value over sulphuric acid to two.

(6) Double chloride of copper and amonium with two atoms water.

The disposition of the protocyanide of iron and of the cyanide of copper to combine with two atoms of cyanide of potassium may depend upon the cyanides of iron and copper possessing two atoms of constitutional water.

VIII.—On the Theory of Voltaic Circle—1839.

From "Brit. Assoc. Report," 1839 (Pt. ii.), pp. 29-31.

The polar molecules of a salt contain negative and positive, or rather chlorous and zincous affinities, called also halogenous and basylous. (Graham's elements of Chemistry, 1850, p. 239, etc.) Explanation of the apparent travelling of hydrogen to the copper plate, by a series of transferences, beginning with the first partially fixed atom of hydrogen (in the case of hydrochloric acid), *i.e.* by a propagation of a decomposition through a chain of particles of the acid (see also Elements of Chemistry, p. 272, etc.)

IX.—On the Constitution of the Sulphates, as illustrated by late Thermometrical Researches—1842.

From "Chem. Soc. Mem.," i., 1841-43, pp. 82-84; "Phil. Mag.," xx., 1842, pp. 539-541.

No heat evolved in uniting sulphate of magnesia with sulphate of potash, some with sulphate of ammonia, but on stirring the latter when the double salt fell the temperature rose 5°·40 F. (3° C.), and fell on resolution. No heat of combination, because sulphate of potash and water are equicalorous in the constitution of such salts.

X.—Experiments on the Heat disengaged in Combinations. Part 1—1842.

From "Chem. Soc. Mem.," i., 1841-43, pp. 106-126—ii., 1843-45, pp. 51-70. "Annal. de Chemie," viii., 1843, pp. 151-180; xiii., 1845, pp. 188-216. "Erdm. Journ. Prak. Chem.," xxx., 1843, pp. 152-183. "Phil. Mag.," xxii., pp. 329-352; xxiv., 1844, pp. 401-420.

Sulphuric acid.
Hydration of magnesium sulphates.
Sulphates and chromates of the potash family.
Double sulphates.

Table of heat absorbed by equivalent quantities of crystallized salts on dissolving in water

Simple relations observed between the heat disengaged by the sulphates of magnesia and zinc, which appear to belong to one class, whilst the sulphates of water, copper, and manganese belong to another.

XI.—Experiments on the Heat disengaged in Combinations. Part II.—1843.

Neutralization of various acids by hydrate of potash.

1. Neutralization of potash by nitric and hydrochloric acids.
2. ,, potash by sulphuric acid.
3. ,, bichromate of potash by hydrate of potash.
4. ,, acetic acid by hydrate of potash.
5. ,, oxalic acid by hydrate of potash.
6. ,, bicarbonate of potash by hydrate of potash.
7. ,, arsenic and phosphoric acids by hydrate of potash.

XII.—On the Diffusion of Liquids—1849.

From "Phil. Trans.," 1850, pp. 1-46, 805-836; 1851, pp. 483-494. "Annal. de Chemie," xxix., 1850, pp. 197-229; "Brit. Assoc. Report," 1851 (Pt. 2), p. 47; "Chem. Soc. Journal," iii., 1851, pp. 60-67; "Jour. de Pharm.," xix., 1851, pp. 394-401; "Liebig. Annal.," lxxvii., 1851, pp. 56-89, 129-160; "Phil. Mag.," xxxvii., 1850; pp. 181-198, 254-281, 341-349.

Any substance in solution is diffused uniformly through the mass of the solvent by a spontaneous process.

The subject has been obscured by the experiments being made with a membrane which imbibes the substance and produces endosmose, not connected with diffusibility. A diffusibility like that of gases would afford means of separating bodies, and present a scale of densities for substances in solution analogous to vapour densities. Gay-Lussac's theory. Chemical combination attended solution with cold; dissimilar bodies combine, whilst soluble substances and their solvents are like, or analogous. Solubility is not the same as the intensity of the solvent force, the gradations of which may depend on unequal diffusibility.

Diffusion of liquid or dissolved carbonic acid slow compared with gaseous.

Mode of experimenting without a diaphragm.

Solutions of salts of the same density diffuse equally.

1. Characters of liquid diffusion. Diffusion of chloride of sodium.

Quantity diffused closely proportioned to the quantity of salt.

Diffusion increases with the temperature. Nearly the same for eight days, but diminishing.

2. Diffusion of various salts and other substances. 20 salt to 100 water at 60°·5 (15°·8 C.) for eight days. Salt, sugar, gum, albumen. Sugar less than half the diffusibility of chloride of sodium.

The diffusion of albumen very much lower than of saline bodies.

Chloride of sodium appears 20 times more diffusible; actually more so, as nearly one-half the matter diffused from the first consists of inorganic salts. Value of this low diffusibility in retaining serous fluids in the blood vessels.

Diffusion of solutions of 10 salt to 100 water, at 59°·5 F. (15°·3 C.)

Do. do. do., at 37°·5 F. (3°·05 C.)

Near equality of certain isomorphous salts.

Diffusion of acid solutions, 4 acid to 100 water, at 59°·3 F. (15°·1 C.)

Considerable latitude in the diffusibility.

3. Diffusion of ammoniacal salts of copper.

4. Diffusion of mixed salts.

Inequality of diffusion is not diminished but exaggerated in mixtures. Same observed of mixed gases.

5. Separation of salts of different bases by diffusion. The potash salts more diffusive than the soda salts. Experiments. Sea salt. Slowness of diffusion.

In the sea salt does magnesium exist as a chloride or sulphate? Will diffusion show this by taking out the most diffusible? Or will the most diffusible, the chloride, form because of its opportunities to diffuse? Liquid diffusion, as well as gaseous evaporation, can produce decomposition.

6. Decomposition of salts by diffusion. Bisulphate of potash. Potash alum. Ammoniated sulphate of copper. Alkaline salts with lime.

7. Diffusion of double salts. A mixture of sulphate of magnesia and sulphate of potash gave in diffusion the sum of the separate diffusions. The salts probably not combined immediately on dissolving.

8. Diffusion of one salt into the solution of another salt. Chloride of sodium does not resist carbonate of soda diffusing into it. Sulphate of soda does. Nitrate of potash is not resisted by nitrate of ammonia, although isomorphous. They are inelastic to each other, like two gases.

At a certain pressure attraction impairs the elasticity of a gas, so at a certain saturation the salt molecules tend to crystallize.

Further analogy between liquid and gaseous diffusion.

Diffusion of salts of potash and ammonia. Vials for diffusion holding 2,080 grains (134·74 grammes), outside vessel or water atmosphere 8,750 grains (or 571·1 grammes). Density 2, 4, $6\frac{2}{3}$, and 10 to 100 water by weight. Some at two temperatures.

Diffusion of carbonate of potash, sulphate of potash, and sulphate of ammonia. Sensibly equal except at the densest point.

Diffusion of chromate of potash and acetate of potash. Close correspondence, even to the 10 per cent. solution.

Diffusion of bicarbonate of potash and bichromate of potash. Close approximation: so that equality is not confined to isomorphous salts.

Diffusion of nitrate of potash and nitrate of ammonia. A slight superiority in the latter.

Diffusion of chloride of potassium and chloride of ammonium. Agree well: related to the preceding nitrates. Crystallizing attraction in strong solutions resisting diffusion.

Diffusion of chlorate of potash. Inferior to the nitrate. Its less solubility may be connected with a tendency to crystallize, uniformity of diffusion greater in weak solutions.

Diffusion of salts of the sulphate of potash class. Diffusion of 1 per cent. solutions. Ferrocyanide and ferricyanide of potassium.

Diffusion of salts of the nitre class.

Nitrate of potash and carbonate of potash.

Times of equal diffusion. A 4 per cent. solution of nitrate of potash diffused for 7 days, or as 1 to 1·4142, the square root of 2. Leading to the idea of solution densities, and further analogy with gases. Further trials.

Hydrate of potash. Compared with nitrate and sulphate.

Diffusion of salts of soda.

Diffusion of sulphate and carbonate of soda. Nitrate of soda.

Relation of salts of potash to salts of soda. Times of equal diffusibility as the square root of 2 to that of 3.

Diffusion of sulphate of magnesia.

Has half the diffusibility of sulphate of potash, and one-fourth that of the hydrate at 52° F. (12°·2 C.) Sulphate of zinc differed from sulphate of magnesia 4 per cent., although isomorphous.

Table of solutions of 1 and 2 salt to 100 water.

Summary of results:—Diffusion a property of a fundamental character. Supplies the densities of a new kind of molecules.

Relations in diffusion refer to equal weights, not to atomic weights, or to larger molecules, if not of equal weight, of weights with a simple relation to each other. Classes of equidiffusive substances. Division of salts of potash. Separation of salts by diffusion. Decomposition by diffusion. Use in the study of endosmose.

Supplementary Observations on the Diffusion of Liquids—1850.

Diffusion of hydrochloric acid. One of the most diffusive substances. Effect of time.

Diffusion of hydriodic acid, hydrobromic acid, and bromine.

Diversity of physical properties compatible with equal diffusibility in substances which are isomorphous.

Hydrocyanic acid. Nitric acid.

Sulphuric acid. Chromic acid.

Acetic acid. Sulphurous acid.

Ammonia.

Alcohol.

Nitrate of baryta.

Nitrate of strontia. Nitrate of lime.

Acetate of lead. Acetate of baryta.

Chloride of barium. Chloride of strontium.

Chloride of calcium.

Chloride of manganese. Nitrate of magnesia. Nitrate of copper.

Protochloride of iron. Sesquichloride of iron.

Sulphate of magnesia.

Sulphate of zinc.

Sulphate of alumina.

Nitrate of silver. Nitrate of soda.

Chloride of sodium.

Chloride of potassium.

Iodides and bromides of potassium and sodium.

Chloride of ammonium.

Dichloride of copper. Diffusion diminished by excess of hydrochloric acid. Same effect of acid on chloride of sodium. Effect of acids.

Bicarbonate of potash. Bicarbonate of ammonia.

Bicarbonate of soda.

Hydrochlorate of morphine.

Hydrochlorate of strychnine. Observations in this paper favour the existence of a close similarity or equality in diffusibility between certain classes or substances. Chlorides and nitrates and their acids show this, isomorphous salts also.

Additional Observations on the Diffusion of Liquids—1851.

In the following the salts of potash and soda only are used, and in four different proportions. Hydrate of potash.

Hydrate of soda.

Carbonate of potash.

Carbonate of soda.

Comparison of potash and soda. Sulphate of potash.

Sulphite of potash.

Sulphite of soda. Hyposulphite of potash. Hyposulphite of soda.

Sulphovinate of potash. Sulphovinate of soda. Oxalate of potash.

Sulphate and oxalate compared. Oxalate of soda.

Acetate of potash. Sulphate and acetate compared.

Acetate of soda. Acetates of soda and potash compared.

Tartrate of potash.

Tartrate of soda. Tartrate of potash and soda compared. Double tartrate of potash and soda decomposed by diffusion. In nine pairs of potash and soda salts the potash salts uniformly exceed the soda in diffusibility, the ratio sensibly the same, the hydrates not included.

XIII.—On the Application of Liquid Diffusion to produce Decompositions—1849.

From "Chem. Soc. Journ.," vol. iii., p. 60, 1851.

Observations made on the spontaneous diffusion into pure water of several salts already dissolved in 100 times their weight of

water. Apparatus as before. The water of the water jar is an atmosphere into which the salts diffuse from the solution phial within. Together they form a diffusion cell. Time, seven days, unless stated otherwise. Temp., 50° F. (10° C.)

Salts diffuse from a one-per-cent. solution in equal times.

Decomposition of sulphate of potash by lime in diffusion cells.

Decomposition of sulphate of soda. Potash salt most decomposed.

Alkaline chloride very slightly decomposed. Decomposition of sulphates by lime in dilute solutions, which cannot deposit sulphate of lime. Decomposition of sulphates by carbonates of lime.

Effect in the soil. No decomposition in saturated solutions of chlorides.

An agency in the soil by which the alkaline carbonates required by plants may be formed from the chlorides of potassium and sodium, as well as from the sulphates. This brought into action by top-dressing with lime.

XIV.—On the Concentration of Alcohol in Sömmering's Experiments—1854.

From "Brit. Assoc. Report," 1854, pt. ii., p. 69.

The alcohol was, by Sömmering, concentrated in a bladder; it was here shown that gelatine had the same effect.

XV.—Liquid Diffusion applied to Analysis—1861.

From "Phil. Trans.," 1861, pp. 183-224 ("Roy. Soc. Proc.," xi., 1860-62, pp. 243-247; "Chem. Soc. Journ.," xv., 1862, pp. 216-270; "Liebig Annal.," cxxi., 1862, pp. 1-77, cxxiii., 1862, pp. 90-112; "Nuovo Cunento," xv., 1862, pp. 92-94; "Paris Comptes Rendus," liii., 1861, pp. 275-279; "Phil. Mag.," xxiii., 1862, pp. 204-223, 290-306, 368-380; "Poggend. Annal.," cxiv., 1861, pp. 187-192).

Volatility a means of separating bodies. Diffusion similar in character. Hydrate, sulphate of potash, etc., "volatile" as regards diffusion. The fixed class are silicic acid, albumen, gums, etc.: crystalline bodies the type of first; gelatine the type of colloids. Distinction intimate molecular. The crystalloid state is statical, the colloid dynamical.

Colloidal has energia. The source of force in vital phenomena.

Colloid substances assisting diffusive separations. Starch and pectin greatly resist passage of less diffusive substances, and entirely cut off colloid substances. A mere film of jelly is enough.

Instances with sized paper. Not as a filter. Only molecules permeate, and not masses. The water of the colloid is in a state of combination, although feeble, and cannot be used as a medium for diffusion. The crystalloid can separate the water, molecule by molecule, and make its way through the gelatinous septum. This action called dialysis.

Vegetable parchment or parchment paper made by M. Gaine. Unsized paper dipt in sulphuric acid. Dialysing vessel or saucers of paper. Jar diffusion explained.

Diffusion of 10 per cent. solutions of chloride of sodium, sugar, gum, and tannin in fourteen days, at 10° C.

Diffusion of sulphate of magnesia, albumen, and caramel for fourteen days.

Diffusion of chloride of sodium in different times.

Diffusion of a 10 per cent. solution of cane sugar in different times.

Hydrochloric acid compared with salts, sugar, and albumen. Diffusion in alcohol of iodine and acetate of potash. Diffusion of alcoholic solution of resin.

Diffusion of 5 per cent. solution of chlorides of potassium and sodium.

Diffusion of 5 per cent. solution of chloride of sodium and sulphate of soda at 10° C. for seven days.

Same for fourteen days. Can two unequally diffusive metals be separated by varying the acid?

Diffusion of 5·12 per cent. chloride of potassium and 4·88 of sulphate of soda for seven days at 14° C.

Diffusion of 4·01 per cent. chloride of sodium and 5·99 of sulphate of potash for seven days at 14° C. Effect of temperature on diffusion.

Dialysis.

Diffusion of a 10 per cent. solution of chloride of sodium in the jelly of gelose for eight days at 10° C. A crystalloid passes through a firm jelly with little or no abatement of velocity.

Heat. The effect of heat increasing diffusion is diminished in dialysis. Bell jar. Bulb dialyser.

Effect of volume of liquid in the dialyser. Effect of acids.

Dialysis through parchment paper during twenty-four hours at 10°—15° C.

Dialysis through animal mucus during twenty-five hours at 10° —15° C.

Dialysis through parchment paper during twenty-four hours at 12° C.

Purification of colloid substances by dialysis.

Crystalloids eliminated by diffusion. Soluble silicic acid. Hydrochloric acid and chloride of sodium removed from it in a hoop dialyser in four days. Pure solution of silicic acid, limpid and colourless, preserved a few days.

Coagulated by earthy or alkaline carbonates and carbonic acid, precipitated on calcareous stone without penetrating; acid like carbonic acid, precipitated by certain other colloids (ordinary silicate of soda not colloidal). Soluble silicic acid forms a peculiar class of compounds also colloidal.

Silicate of gelatine. Colli-silicates or cosilicates.

Cosilicic acid. Albuminic acid. Soluble alumina made by placing on the dialyser a solution of alumina in chloride of aluminium. Very unstable. Coagulated by extremely minute amounts of salts. Colloidal alumina has a high atomic weight, like cosilicic acid.

Soluble metalumina. Crum's discovery. Heating a binacetate to the boiling point of water, and keeping thus for several days; also by dialysing an acetate of alumina that has been altered by heat; not a mordant. Soluble peroxide of iron. Preparation.

Solution of the peroxide in the chloride goes on for months. Slow action characteristic of colloids.—Very unstable solution. Separation by diffusion.

Soluble metaperoxide of iron. Ferrocyanide of copper.

Neutral Prussian blue.

Ferrocyanide of iron, soluble in oxalic acid and binoxalate of potash. Sucrate of copper. Sucrate of peroxide of iron. Sucrate of peroxide of uranium. Sucrate of lime. Soluble chromic oxide. Hydrated uranic oxide and glucina. It appears that the hydrated peroxides of the aluminous type when free are colloid bodies; two species exist, of which alumina and metalumina are the types.

The double type in fibrin of blood.

Peroxide of tin. Metastannic acid. Titanic acid.

Dialysis of organic colloid substance.—Tannin diffuses, at most, 200 times less than chloride of sodium. Gum, 400 tin diffusive than chloride of sodium.

Gummic and metagummic acids.—Gummate of gelatine, dextrin, caramel, varieties of. Cane sugar, albumen.

Emulsin. Coagulated albumen. Gelatinous starch. Extract of flesh. Separation of arsenious acid from colloidal liquids.

·95 per cent. of the arsenious acid diffused out in 24 hours. Amount with albumen and gum.

Arsenious acid with other organic substances.

Colloidal condition of matter.—Colloids and crystalloids different worlds of matter, distinct as the material of a mineral and the material of an organized mass. Colloids may be soluble or insoluble. Easily thrown out of solution by crystalloid. Crystalloids sapid; colloids insipid.

Tendency to change in colloids.—Colloids equivalents high. Possibly a collection of crystalloid molecules.

Gelatine an important colloidal base.

Ice.—Colloidal and crystalline. No abrupt transitions.

Osmose.—Caused by hydration and dehydration of the membrane. Outer surface being pure water is most hydrated. With full hydration through the membrane osmose is checked. Weak alkalies swell the colloids, and cause extreme osmotic sensibility.

XVI.—On Capillary Transpiration of Liquids in relation to Chemical Composition—1861.

From "Phil. Trans.," 1861, pp. 373-386 ("Roy. Soc. Proc.," xi., 1860-62, pp. 381-384; "Chem. Soc. Journ.," xv., 1862, pp. 427-445; "Paris Comptes Rendus," liii., 1861, pp. 774-777).

Poiseuille.—Greatest retardation of alcohol is with six equivalents of water.

Nitric acid.—Retardation greatest with three atoms water.

Sulphuric acid.—Twenty-four times slower than water. Least transpirability in the crystallizable hydrate, or one atom of water added to SHO_4. Transpiration time of water 109 seconds.

Acetic acid.—The hydrate $C_4H_4O_4 + H_2O$ has a transpiration time 2·7 times longer than water.

Butyric acid.—With three equivalents water greatest retardation.

Valerianic acid.—Retarded most by two equivalents of water.

Formic acid does not follow the same rule.

Hydrochloric acid.—Its retardation indicates a 12-hydrate. No appearance of a point indicating a 16-hydrate.

Alcohol.—Poiseuille's fundamental discovery confirmed by numerous experiments. Methylic alcohol, 6-hydrate of amylic alcohol.

Ethers.—Formiate, acetate butyrate, and valerianate of ethyl, give transpiration times progressively rising—this may be connected with the increased weight of the molecule.

Acetone.—Time greatest with twelve equivalents of water.

Glycerine.—No point of retardation found.

Importance of observing transpiration. Retardation of hydrates may be caused by the increased size of the molecules, but it is possible to conceive a decomposition caused by the friction of passage and the propelling power lost by conversion into heat.

Table of the transpiration of water at different temperatures.

Table of the transpiration of alcohol at different temperatures.

XVII.—On the Properties of Silicic Acid and other Analogous Colloidal Substances—1864.

From the "Journal of the Chemical Society," 1864.

Hydrate of silicic acid soluble according to hydration. A jelly with 1 per cent. of silicic acid gives a solution with one of that acid in 5,000. Time alone may cause coagulation which is opposed by concentration and warmth.

Pectization by pounded graphite. No crystallization. Colloids transpire slowly. The particles aggregate.

Alcohol and silicic acid.

Ether and silicic acid. Glycerine and silicic acid.

Sulphuric acid and acetic acid.

Restoration of the liquid from the pectose state. Liquid stannic and metastannic acids.

Liquid titanic acids. Liquid tungstic acid.

Molybdic acid.

UNCLASSED PAPERS.

I.—On the Heat of Friction—1826.

From "Annals of Philosophy," xii., 1826, pp. 260-262.

A speculation on the separate existence of heat.

II.—Alcohol derived from the Fermentation of Bread—1826.

From "Annals of Philosophy," xii., 1826, p. 363.

There was found alcohol equal to 0·3 to 1 per cent. of the flour employed.

III.—Effect of Animal Charcoal on Solutions—1830.

From "Quart. Journ. of Science," i., 1830, pp. 120-125 ("Dingler Polytechn. Journ.," xl., 1831, pp. 443-446; "Poggend. Annal.," xix., pp. 139-144).

Here it is shown by several instances, chiefly of metallic salts, that the charcoal removes more than mere colouring matter from solution.

IV.—Note on the Preparation of Chlorate of Potash—1841.

From "Chem. Soc. Mem.," 1841-43, pp. 5-7.

Loss of oxygen by acting with chlorine on carbonate of potash alone. Recommends addition of hydrate of lime. The chlorine attacks the potash, and the lime takes the carbonic acid at the same time. Similar result of secondary action found when sulphate of soda is added to lime, which mixture takes up two equivalents of sulphuretted hydrogen to one of lime.

V.—Lettre de M. Graham à M. Dumas—1842.

From "Annal. de Chimie," iv., 1842, pp. 177-186.

Some ideas arising from the law of substitution—even an isolated element, such as a metal, held to be made up of several parts. Combination the natural state of matter. Electro-chemical theory, and mode of writing the symbols under this theory. A view of the constitution of several molecules of compound bodies.

VI.—Note on the Useful Application of the Refuse Lime of Gas-works—1845.

From "Chem. Soc. Mem.," ii., 1843-45, pp. 358-359; "Erdm. Jour. Prak. Chem.," xxxvi., 1845, pp. 48-49; "Frankl. Inst. Journ.," xi., 1846, pp. 281-282.

By exposure to air refuse lime becomes quickly oxidized, and one-sixth of its weight has been taken from it as crystallized hyposulphite of lime by a single crystallization.

VII.—Note on the Existence of Phosphoric Acid in the Deep Well Water of the London Basin—1845.

From "Chem. Soc. Mem.," ii., 1843-45, pp. 392, 393; "Bibl. Univ.," lx., 1845, pp. 385, 386.

Deposits carbonate and phosphate of lime. Green confervæ grow readily. Does the value of water for irrigation depend on the phosphoric acid?

VIII.—Observations on Etherification—1851.

From "Chem. Soc. Journ.," iii., 1851, pp. 24-28; "Journ. de Pharm.," xviii., 1850, pp. 124-130; "Liebig's Annal., lxxv.," 1850, pp. 108-116.

The most direct method of preparing ether is to add 4 to 8 of alcohol to 1 of strong sulphuric acid of 83 per cent., and to heat to 320° F. (160° C.) under pressure. No distillation or sensible formation of sulphovinic acid necessary. Action of the acid compared to that on the essential oils. A polymerizing action.

ERRATUM.

On page 261, line 18, *read* "eight hundred years," instead of "five hundred years."

REPORTS OF SECTIONS.

[Read before the Society on 30th April, 1884.]

1. Report of the Architectural Section for Session 1883-84.

During the Session eight Meetings have been held. The following is a list of the papers read at those Meetings:—

November 19, 1883.—Opening address by the President, James Sellars, Esq.; and John Hay, Esq., Heating and Ventilating Engineer, read a paper, subject, "The Application and Comparative Value of the different kinds of Air-Warming Apparatus."

December 3, 1883.—John Honeyman, Esq., Architect, read a paper, subject, "Free Spaces in Densely Populated Districts, and how to Gain them."

December 17, 1883.—Daniel Wilkie, Esq., Measurer, read a paper, subject, "Measuring, its Uses and Abuses;" and the discussion of paper read by Mr. John Honeyman on December 3 was continued.

January, 21, 1884.—William Forrest Salmon, Esq., Architect, read a paper, subject, "Some observations on the Ventilation of Buildings."

February 4, 1884.—John Dansken, Esq., Measurer, read a paper, subject, "Notes on the Fire-Resisting Properties of the leading Building Materials;" and Alexander Muir, Esq., Builder, one on "The Past and Present of Mason Work."

February 18, 1884.—Andrew Wells, Esq., Decorator, read a paper, subject, "The Rise and Development of Ornament."

March 3, 1884.—David Thomson, Esq., Architect, read a paper on "Sewage;" and A. Lindsay Miller, Esq., one on "Sanitary Plumber Work."

March 17, 1884.—Discussion on paper read by Mr. John Dansken on February 4, and the closing address of the President, James Sellars, Esq.

The thanks of the Section are due to all these gentlemen.

The Annual Business Meeting was held on the evening of Monday, 17th March, 1884, when the following gentlemen were elected to office:—

President—James Sellars, Esq., Architect.

Vice-Presidents—William Landless, Esq., Architect; and Alex. Muir, Esq., Builder.

Treasurer—James Howatt, Esq., Measurer.

Secretary—A. Lindsay Miller, Esq., Architect, 121 West Regent Street.

Members of Council—David Thomson, Esq., Architect; W. F. Salmon, Esq., Architect; John Honeyman, Esq., Architect; T. L. Watson, Esq., Architect; Thomas Gildard, Esq., Architect; John Dansken, Esq., Measurer; William Howitt, Esq., Measurer; Robert Scott, Esq., Measurer; W. P. Buchan, Esq., Sanitary Engineer; William Gilfillan, Esq., Marble Cutter.

A. Lindsay Miller, Architect,
Secretary of Section,
121 West Regent Street.

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2. Report of the Chemical Section for Session 1883-84.

During Session 1883-84 this Section held five General Meetings, at which the average attendance was 12.

The Associates were also invited to attend two meetings of the Philosophical Society, at which communications from the Chemical Section were read.

On February 20th, the second triennial "Graham" Lecture, subject, "The Life and Work of Thomas Graham, late Master of the Mint," prepared by Dr. R. Angus Smith, F.R.S., was communicated to the Philosophical Society, and the Chemical Section conjointly, by Professor Ferguson, one of the Vice-Presidents of the Chemical Section.

The following is a list of papers contributed to the Section:—

November 12, 1883.—*Opening address by the President (R. R. Tatlock, Esq.).

November 26, 1883.—(1) Annual Business Meeting. (2) * "On the Separation of Cobalt and Nickel," by Dr. Clark.

December 10, 1883.—* "On the Use of Litmus, Methyl Orange, Rosolic Acid, Phenacetolin, and Phenolphthaleïn as Indicators: Part II.," by Mr. Robert T. Thomson.

January 14, 1884.—(1) * "Notes on the Analysis of Commercial Carbonate of Potash," by Mr. Robert T. Thomson; (2) "On the Molecular Structure and Constitution of the Methyl and Ethyl Alcohols; as also, of their numerous Oxidation Products and Derivatives," by Dr. O. Richter.

February 11, 1884.—(1) "On Flour and Bread, and some other Alimentary Substances," by Dr. Wallace; (2) "On the Use of Litmus, &c., as Indicators: Part III.," by Mr. R. T. Thomson.

The papers marked with an asterisk (*) were recommended to the Council of the Philosophical Society for publication in the Proceedings.

The following were the communications from the Chemical Section to the Philosophical Society:—

January 19.—By Mr. J. J. Coleman—(1) "On a new method of Measuring the Heat-Conducting Power of various Materials, such as Wool, Cotton, Hair, &c.;" (2) "On a new Thermometer for Measuring Low Temperatures, with Illustrations;" (3) "On Mithoff's Metallic Spiral Hygroscope, with Illustrations."

February 6.—By Dr. J. J. Dobbie—"On the Recent Progress of Chemistry at Home and Abroad; a Plea for the Teaching of Higher Chemistry in this Country."

Five gentlemen were elected Associates of the Section in the course of the Session.

GEORGE G. HENDERSON,
Hon. Sec.,
CHEMICAL LABORATORY, UNIVERSITY OF GLASGOW.

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3. REPORT OF THE BIOLOGICAL SECTION FOR SESSION 1883-84.

April 26, 1882.—During the Session the President of the Section delivered an address, and Dr. W. Limont read a paper before the Philosophical Society.

D. C. M'VAIL, M.B.,
Sec. of Section,
ST. JAMES TERRACE, HILLHEAD.

4. Report of the Geographical and Ethnological Section for Session 1883-84.

At the Annual Meeting of the Society, held on 21st November, 1883, the following gentlemen were appointed office-bearers of the Section:—

President—W. G. Blackie, Ph.D., F.R.G.S.

Vice-President—James Stevenson, F.R.G.S.

Members of Council—Mr. Thomas Carlile, Dr. J. Christie, A.M.; Mr. Michael Connal, Mr. William Ewing, Mr. James Grierson, Mr. Maxwell Hannay, Mr. Wm. Ker, Mr. Thomas Muir, M.A., LL.D., F.R.S.E.; Mr. Alex. Scott, Mr. John Steel, and Mr. W. Renny Watson.

Secretary and Treasurer—Geo. A. Turner, M.D., C.M., 1 Clifton Place, Sauchiehall Street.

Three papers from this Section were read before General Meetings of the Society during the Session—1st, an opening address by Dr. Blackie, as President of the Section, on "Geography and Ethnology, what these Embrace," on 5th March; 2nd, a paper by the Rev. Alex. Williamson, LL.D., of China, "On some of the Chief Features of the Physical Geography, including the Geology, of China," also on 5th March; and 3rd, a paper by Dr. Blackie, President, entitled, "Sketch of the present State of our Knowledge of the Island of New Guinea," on 16th April.

G. A. Turner, M.D.,
Secretary,
1 Clifton Place, Sauchiehall Street.

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5. Report of the Sanitary and Social Economy Section for Session 1883-84.

The Sanitary and Social Economy Section had two meetings during the past Session, and had the Amendment of the Public Health Act of Scotland again under discussion. The Section recommended three papers to be read at the General Meetings of the Society. No other business was transacted during the Session.

Eben. Duncan, M.D.,
Secretary,
4 Royal Crescent, Crosshill.

MINUTES OF SESSION.

25th April, 1883.

The Eleventh and Last Ordinary Meeting of the Philosophical Society of Glasgow for Session 1882-83 was held on the 25th day of April, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Wallace, President, in the Chair.

1. The Minutes of the last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were confirmed, and signed by the Chairman.

2. The following new Members were proposed, to be balloted for at the first Meeting of next Session:—

Mr. William Ferguson, 116 St. Vincent Street. Proposed by Mr. James Thomson, F.G.S., Mr. A. Robertson, and Professor M'Kendrick.

Mr. Robert Baird Paterson, Agent, Commercial Bank of Scotland, 180 Trongate. Proposed by Mr. James Thomson, F.G.S., Mr. A. Robertson, and Professor M'Kendrick.

Dr. Turner, 2 Bellgrove Street. Proposed by Mr. Thomas Muir, M.A., Dr. Christie, and Professor M'Kendrick.

3. Mr. Robert R. Tatlock read a paper prepared by Mr. George MacRoberts, F.C.S., Nobel's Explosives Company, Ardeer, "On the Manufacture and Properties of Nitro-glycerine." Mr. Tatlock showed a number of experiments illustrating the manufacture and properties of nitro-glycerine. After some discussion, he and Mr. MacRoberts received the cordial thanks of the Society.

4. The following Memorial to the Earl of Rosebery and to the Lord-Advocate regarding the amendment of the Public Health (Scotland) Act, 1867, was approved, and the President and Secretary were authorised to sign it on behalf of the Society.

(Printed at page 544 of *Proceedings*, vol. xiv.)

5. As a matter of urgency the President moved the suspension of the Standing Orders so as to permit a motion to be discussed of which previous notice had not been given. This was agreed to. Mr. Mactear then moved, and Mr. Mayer seconded, a motion that the following gentlemen be appointed a Committee to watch the progress of legislative measures regarding the Patent Laws, and to petition the Houses of Parliament in terms similar to the petition presented by the Society in June, 1880 :—

Sir William Thomson, Professor James Thomson, Mr. A. Whitelaw, Mr. Hunt, Mr. Day, Mr. J. Boyd, Mr. E. M. Dixon, Dr. Wallace, Mr. James Mactear, Mr. Fairweather, Mr. W. R. W. Smith, Mr. John Mayer, and Dr. M'Kendrick.

The motion was unanimously agreed to.

6. On the motion of Mr. Archibald Robertson, the Meeting nominated Dr. Henry Muirhead and Professor M'Kendrick to be Delegates from this Society to the Meeting of Representatives of similar Societies to be held at the Meeting of the British Association at Southport in September next.

7. The Secretary read the Annual Reports from the Architectural, Chemical, and Sanitary and Social Economy Sections. These were ordered to be printed in the *Proceedings*. No report from the Biological Section was presented, but the Secretary was authorised to receive one from the Secretary, and to print it in the *Proceedings*.

8. Mr. John Mayer gave notice of the following motion for the first Meeting of next Session :—"That the Society vote a sum of not exceeding Twenty Pounds in aid of a fund for erecting a Meteorological Observatory on Ben Nevis."

(Signed) WILLIAM WALLACE.

7th November, 1883.

The Philosophical Society of Glasgow held its First Meeting for Session 1883-4, on the evening of the 7th November, 1883, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. William Wallace, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following were proposed for election as Members of the Society, viz.:—

Mr. Arthur Hart, Woodlands Terrace. Recommended by Mr. Archibald Robertson, Dr. W. J. Fleming, and Professor M'Kendrick.

Mr. George A. Mitchell, Coal Master, 67 West Nile Street. Recommended by Mr. Archibald Robertson, Mr. Michael Connal, and Professor M'Kendrick.

Mr. William Grant Paton, 11 Kerrsland Terrace, Hillhead. Recommended by Mr. Walter E. Wingate, Mr. George Miller, and Mr. Edward Gillespie.

Mr. James Thomson Tullis, Anchorage, Burnside, Rutherglen. Recommended by Mr. George M'Callum, Dr. Henry Muirhead, and Mr. John Kirsop.

3. The President delivered an Address on "Crystalline Form," illustrated by numerous experiments and a fine collection of various kinds of Crystals. On the motion of Mr. J. J. Coleman, Dr. Wallace was accorded a very hearty vote of thanks.

4. After some discussion, Mr. John Mayer withdrew his motion regarding the proposed grant to the Ben Nevis Observatory Fund.

5. On the motion of the President, Mr. W. E. Wingate and Mr. Robert Goodwin were appointed Auditors of the Treasurer's Accounts for the past year.

6. The President announced that the following gentlemen had been duly elected Members of the Society, viz.:—

Mr. Robert J. Bennett, 8 Holland Place. Recommended by Mr. James Paton, F.L.S., Professor M'Kendrick, and Dr. J. M'Gregor Robertson.

Mr. J. M. Campbell, Assistant Curator, Kelvingrove Museum. Recommended by Mr. James Paton, Professor M'Kendrick, and Dr. J. M'Gregor Robertson.

Mr. Henry Dyer, M.A., C.E., Dunrowan, Lenzie. Recommended by Mr. David Sandeman, Mr. E. M. Dixon, B.Sc., and Mr. John Mann, C.A.

Mr. William Ferguson, 116 St. Vincent Street. Recommended by Mr. Archibald Robertson, Professor M'Kendrick, and Dr. David Newman.

Mr. Robert Baird Paterson, Agent, Commercial Bank of Scotland, 180 Trongate. Recommended by Mr. Archibald Robertson, Professor M'Kendrick, and Dr. David Newman.

Mr. Alexander Sinclair, Ajmere Lodge, Langside. Recommended by Mr. John Kirsop, Mr. John Barclay, and Mr. Archibald Robertson.

Mr. D. Sinclair, Electrical Engineer, National Telephone Coy. (Limited), 8A Royal Exchange Buildings. Recommended by Mr. Wallace Fairweather, C.E., Dr. David Newman, and Professor M'Kendrick.

Mr. R. D. Smillie, M.S.T.E. and E., Electrician, National Telephone Coy. (Limited), 13 Royal Exchange Square. Recommended by Mr. Wallace Fairweather, C.E., Dr. David Newman, and Professor M'Kendrick.

George Turner, M.D., 1 Clifton Place, Sauchiehall Street. Recommended by Mr. Thomas Muir, M.A., Dr. James Christie, and Professor M'Kendrick.

Mr. E. D. Dunlop, Iron Merchant, 68 St. Vincent Street, Glasgow. Recommended by Mr. G. A. Waghorn, Mr. John Mann, C.A., and Dr. J. M'Gregor Robertson.

(Signed) WILLIAM WALLACE.

21st November, 1883.

The Philosophical Society of Glasgow held its Eighty-second Annual Meeting on the evening of the 21st November, 1883, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. William Wallace, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Members were admitted :—

Mr. Robert J. Bennett, 8 Holland Place; Mr. J. M. Campbell, Kelvingrove Museum; Mr. Henry Dyer, M.A., C.E., Dunrowan, Lenzie; Mr. William Ferguson, 116 St. Vincent Street; Mr. Robert Baird Paterson, 180 Trongate; Mr. Alexander Sinclair, Ajmere Lodge, Langside; Mr. D. Sinclair, 8A Royal Exchange Buildings; Mr. R. D. Smillie, M.S.T.E. and E., 13 Royal Exchange Square; George Turner, M.D., 1 Clifton Place, Sauchiehall Street; Mr. E. D. Dunlop, 68 St. Vincent Street.

3. The following were proposed for the Membership of the Society :—

Mr. Francis Walter Allan, Merchant, 15 Gordon Street. Recommended by Mr. Michael Connal, Mr. Nathaniel Dunlop, and Mr. Alexander Scott.

Mr. John Edwards, Govanhaugh Dyeworks. Recommended by Mr. J. Walker MacGregor, Mr. John Barclay, and Mr. John Garroway.

Mr. George G. Henderson, B.Sc., 1 Westbourne Terrace, Kelvinside. Recommended by Professor Ferguson, Dr. James J. Dobbie, and Professor M'Kendrick.

Mr. James Goldie, 40 St. Enoch Square. Recommended by Mr. James Howat, Mr. William Howatt, and Mr. A. Lindsay Miller.

Mr. A. C. Macintyre, 4 Park Terrace, Queen's Drive. Recommended by Mr. John Mann, Professor M'Kendrick, and Mr. Archibald Robertson.

Dr. Angus Macphee, 327 St. George's Road. Recommended by Professor M'Kendrick, Mr. John Mann, and Mr. Archibald Robertson.

Mr. Robert George Munsie, 16 Royal Terrace, West. Recommended by Mr. John Birkmyre Wingate, Dr. John Clark, and Mr. James King.

Mr. Joseph F. Newlands, Stockbroker, 28 Renfield Street. Recommended by Professor M'Kendrick, Mr. John Kirsop, and Mr. Robert Paterson.

Mr. Walter Steuart, 12 Pollok Road, Pollokshaws. Recommended by Mr. James Barclay Murdoch, Mr. Archibald Robertson, and Mr. John M. Cunningham.

Mr. John S. Stewart, Measurer, 42 Bath Street. Recommended by Mr. John Mann, Professor M'Kendrick, and Mr. Archibald Robertson.

Mr. David Inglis Urquhart, Merchant, 47 Westbourne Gardens. Recommended by Mr. Charles H. Barclay, Professor M'Kendrick, and Mr. John Mann.

Mr. Charles Watt, Merchant, 13 Dundas Street. Recommended by Mr. William Couper, Mr. Alexander Whitelaw, and Mr. W. E. Wingate.

4. Professor M'Kendrick, Secretary, read the Annual Report by the Council on the state of the Society, which was, on the motion of Mr. Nathaniel Dunlop, seconded by Mr. Archibald Robertson, adopted, and ordered to be printed in the *Proceedings*. The Report was as follows :--

Report on the State of the Society by the Council for Session 1882-3.

I. *Meetings.*—The Society held eleven ordinary and two special Meetings during the Session, which was opened on the 1st of November, 1882, and closed on 25th April, 1883. Eighteen papers were read at these Meetings.

II. *Membership.*—The number of Members on the Roll at the beginning of Session 1882-3 was 676; during the Session 30 new Members were elected, making 706. Of these, 31 have resigned, 3 have left Glasgow—their names being placed on the Suspense List—15 have died, and 2 have been struck off the Roll for non-payment of annual subscriptions; leaving on the Roll, at the beginning of the present Session, 655 Members, being a decrease of 21. Of the 30 new members, 3 became Life Members; 6 Ordinary Members also paid the composition for Life Membership during the Session. On the 31st of January Principal Dawson of Montreal was elected an Honorary Member, in room of the late Dr. Andrew Buchanan, and a vacancy has again been created in the list of Honorary Members by the death of General Sir Edward Sabine. There are at present 19 Honorary Members, of whom 6 are Continental, 4 are American or Colonial, and 9 are British. On the 31st of January the Society elected 6 new Corresponding Members, all of whom are distinguished in science. The number of Corresponding Members is now 10. The total number of Life Members is 54.

III. *Sections.*—During the Session the Architectural Section held 8 Meetings, at which 10 papers were read; of these, 2 appear in the *Proceedings*. The Chemical Section held 10 Meetings, at which 12 papers

were read, and of these 7 appear in the *Proceedings.* The Biological Section contributed the address of its President, which was delivered at an Ordinary Meeting of the Society, and is printed in the *Proceedings.* The Sanitary and Social Economy Section sent 2 papers to be read at Ordinary Meetings of the Society, both of which appear in the *Proceedings.* This Section also spent much time and labour in considering the Amendment of the Public Health (Scotland) Act, 1867, and the results of its deliberations were embodied in a Memorial, which was adopted by the Society, and presented to the Earl of Rosebery and the Lord Advocate.

The Council also reports with satisfaction that a Geographical and Ethnological Section was formed on 11th of April, and Office-Bearers were appointed provisionally until the Annual Meeting. This Section was formed in consequence of the practical interest excited by the valuable geographical paper contributed by Mr. James Stevenson, F.R.G.S.; and it is to be hoped that a department of science of such importance to a great commercial community will receive support by the communication of papers and the exhibition of objects illustrating the manners and customs of little-known races of men. There are now five Sections of the Society, two of which hold Meetings of their own, whilst all contribute to the Ordinary Meetings and to the *Proceedings.*

IV. *Proceedings.*—The *Proceedings* of the Society for 1882-3, Vol. XIV., form a larger volume than usual, containing 24 Papers, 23 Plates, and 3 Maps. For the 3 Maps the Council is indebted to Mr. James Stevenson, and for the cost of printing the 14 beautifully-finished Plates, illustrating Mr. James Thomson's paper, and drawn by Mr. Thomson himself, the Council has to acknowledge the generosity of Dr. Henry Muirhead. It would greatly facilitate the working of the Society, and ensure the early publication of the *Proceedings,* if contributors of papers would have their papers in as complete a form as possible at the time they are communicated to the Society.

V. *Petitions.*—During the Session the Society forwarded Memorials to the Earl of Rosebery and to the Lord Advocate regarding the Amendment of the Public Health (Scotland Act, 1867, and also a Petition to the House of Commons regarding the "Patents for Inventions Bill."

Signed, by Order and on behalf of the Council, by

JOHN G. M'KENDRICK,
Secretary.

5. The Audited Statement of Accounts for Session 1882-83, by Mr. John Mann, the Treasurer, having been printed in the Circular calling the Meeting, was held as read, was approved of, and was ordered to be printed in the *Proceedings.*. A vote of thanks to the Treasurer was carried unanimously. A vote of thanks was also accorded to Mr. W. E. Wingate and Mr. Robert Goodwin, the Auditors. The Statement was as follows:—

(See pp. 370, 371.)

6. Mr. John Robertson, Librarian and Convener of the Library Committee, read the Annual Report on the Library, which was adopted, and was ordered to be printed in the *Proceedings*. The Report was as follows:—

Report of the Library Committee.

Your Committee have pleasure in reporting that the new Catalogue of the Books in the Library of the Society, containing 183 pages, with title, regulations, and contents, was distributed to the Members in January last.

During the past year 912 volumes were issued to 737 Members. Since last Report 249 volumes, 45 parts of works, and 22 pamphlets have been added to the Library. Of the periodicals received 23 are weekly, of which 18 are bought and 5 presented; 3 are fortnightly, of which 1 is bought and 2 presented; 36 are monthly, of which 26 are bought and 10 presented; 21 are quarterly, of which 15 are bought and 6 presented. These form 128 volumes a year.

Exchanges of Transactions and other publications are made with 122 Societies and Public Departments. Correspondence has been opened up with the Wagner Free Institute of Science, Philadelphia.

151 volumes were added to the Library by purchase. 92 volumes, 45 parts, and 22 pamphlets were presented; and the thanks of the Society are due to the donors. Acknowledgment of the presentations during Session 1882-3 will be found in the *Proceedings*, where a complete list of the additions for that year, and of the names of the Societies and Public Departments with which publications are exchanged, has been printed.

182 volumes were bound during the past year, and 9 are still in the hands of the binder.

The number of volumes at present in the Library is 8954.

(Signed) JOHN ROBERTSON,
Convener.

A special vote of thanks was unanimously given to Mr. Robertson.

7. The Society then proceeded to the election of Office-Bearers.

(1) It was moved by Dr. William Wallace, the retiring President, that Dr. Henry Muirhead be elected President for the next three years. The motion was carried by acclamation, and Dr. Muirhead took the chair as President.

(2) It was moved by Mr. Michael Connal, the retiring Vice-President, that Mr. Alexander Scott be elected a Vice-President of the Society for the next three years. The motion was passed unanimously.

Dr. ABSTRACT OF TREASURER'S

1882.—Nov. 1.			
To Balance in Treasurer's hands from last session, . .			£2 12 1
1883.—Oct. 31.			
To Entry-money from 30 New Members, at 21s.,		£31 10 0	
,, Annual Dues from 1 Member for 1881-82, at 21s., . .	£1 1 0		
,, Annual Dues from 590 Ordinary Members for 1882-83, at 21s.,	619 10 0		
,, Annual Dues from 27 New Members for 1882-83, at 21s.,	28 7 0		
		648 18 0	
,, Life Subscription from 3 New Members, at £10 10s., .	£31 10 0		
,, Life Subscription from 6 Old Members, at £10 10s., .	63 0 0		
		94 10 0	
			£774 18 0
,, CHEMICAL SECTION—			
2 Associates for 1881-82, at 5s., . .		£0 10 0	
29 do. 1882-83, at 5s., . .		7 5 0	
			7 15 0
,, ARCHITECTURAL SECTION—			
25 Associates' fees between 16th March, 1882, and 21st March, 1883, at 5s., ...			6 5 0
,, Corporation of Glasgow, Interest on "Exhibition Fund" for year to Whitsunday, 1883—less Income Tax, .			20 1 5
,, Interest from Bank, ...			4 7 0
,, *Proceedings*, Catalogues, &c., sold, . . .			1 5 0
,, Clydesdale Bank, Limited, drawn, . . .			210 0 0
,, Balance due Treasurer, ...			40 7 11½
			£1,067 11 5½

Memo. by Treasurer.—The Amount of the Society's Funds invested in the Bath Street Joint Buildings up to 31st October, 1883, is £3,547 8s. 1½d., of which, Paid in Cash from Society's Funds, £1,547 8 1½

Do. do. from Private Loans, . 500 0 0

Do. from Society's half of £3,000 Bond over Buildings, . . 1,500 0 0

£3,547 8 1½

J. M.

ACCOUNT—SESSION 1882-83. **Cr.**

	£	s.	d.	£	s.	d.
1883.—Oct. 31.						
By Salary to Secretary,	£75	0	0			
,, Allowance for Treasurer's Clerks,	15	0	0			
,, Demonstrations at Lectures, 1881, £20; 1882, 10s.,	20	10	0			
,, Reporting,	2	2	0			
				£112	12	0
,, New Books, Periodicals, and Foreign Periodicals,	£91	19	6			
,, Bookbinding, two years,	63	19	3			
,, Printing Circulars, *Proceedings*, &c.,	249	0	0			
,, Library Catalogues,	94	6	4			
,, Lithographs for *Proceedings*,	29	13	9			
,, Postage and delivery of Circulars, Letters, and Parcels,	36	19	6			
,, Diplomas and Stationery,	6	15	8			
	£572	14	0			
Less, Contributions by Authors to cost of Illustrations,	3	6	0			
				569	8	0
,, Fire Insurance on Library for £5,400,	£5	17	7			
,, Postages, &c.—per Treasurer, £1 15s. 10d.; per Secretary, £7,	8	15	10			
,, Interest on Loans of £300 and £200,	25	0	0			
				39	13	5
,, SUBSCRIPTIONS TO SOCIETIES—						
Ray Society, 1883,	£1	1	0			
Palæontographical Society, 1883,	1	1	0			
				2	2	0
,, CHEMICAL SECTION— Expenses per Treasurer of Section,				5	2	11½
,, ARCHITECTURAL SECTION— Expenses per Treasurer of Section,				7	14	8½
,, SANITARY SECTION— Expenses per Secretary of Section,				0	10	0
,, BATH STREET JOINT BUILDINGS— Society's half of West Mean Gable,				47	6	2½
,, JOINT EXPENSES OF ROOMS— Society's half of Interest on Bond, Insurance, Taxes, Cleaning, Lighting, and Heating, Salaries of Sub-Librarian and Assistant—less half of Revenue from Letting,				143	2	2
,, Clydesdale Bank, Limited, Lodged,				140	0	0
				£1,067	11	5½

GLASGOW, *14th November, 1883.*—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1882-83, have examined the same, of which the above is an Abstract, and have found them correct, the Balance due to the Treasurer at 31st October last being Forty Pounds Seven Shillings and Elevenpence Halfpenny.

(Signed) W. E. WINGATE.
ROBERT GOODWIN.

(3) The President moved the re-election of Mr. John Robertson as Librarian, Mr. John Mann as Treasurer, and Professor M'Kendrick as Secretary, and these were unanimously re-elected to their respective offices.

(4) It was moved by Mr. Nathaniel Dunlop, and seconded by Mr. A. Whitelaw, that Mr. Archibald Robertson, Mr. Michael Connal, Professor Blyth, Principal Jamieson, Mr. James Nicol, and Mr. E. M. Dixon be elected to the six vacancies in the Council occasioned by the retirement by rotation of Dr. Carmichael, Mr. Nathaniel Dunlop, Professor Jack, and Mr. Archibald Robertson, and by the election of Dr. Henry Muirhead as President and of Mr. Alexander Scott as Vice-President. The following gentlemen were also proposed and seconded:—Mr. Robert Goodwin and Mr. J. J. Coleman. The Society then balloted for six Members of Council—Mr. David Mackinlay and Mr. A. Whitelaw being appointed Scrutineers. The Scrutineers reported that the following had the greatest number of votes, viz.:—Mr. Michael Connal, 52; Mr. Archibald Robertson, 51; Professor Blyth, 50; Principal Jamieson, 46; Mr. E. M. Dixon, 46; and Mr. James Nicol, 34. These gentlemen were therefore declared by the Chairman to have been duly elected Members of Council—Mr. Dixon to hold office for two years, in room of Dr. Henry Muirhead, and Mr. Nicol to hold office for one year, in room of Mr. Alexander Scott.

8. Dr. Christie, in accordance with the resolution of the Society of date 11th April, 1883, moved that the following be elected Office-bearers of the Geographical and Ethnological Section:—*President*, W. G. Blackie, Ph.D., F.R.G.S.; *Vice-President*, Mr. James Stevenson, F.R.G.S.; *Secretary*, George A. Turner, M.D.; *Members of Council*—Mr. Maxwell Hannay, Mr. John Steel, Mr. William Ker, Mr. Thomas Carlile, Mr. Michael Connal, Mr. Thomas Muir, M.A., F.R.S.E.; Mr. James Grierson, Mr. W. Renny Watson, Mr. Alexander Scott, Mr. William Euing, and James Christie, M.A., M.D. On the suggestion of Mr. Alexander Scott it was agreed that the names of Members of Council be arranged alphabetically, and that the first four retire at the end of one year, the second four at the end of two years, and the remainder at the end of three years, thus establishing the principle of rotation.

9. The President moved, and Professor M'Kendrick seconded, a motion that the thanks of the Society be given to Dr. William Wallace for the able and zealous manner in which he had discharged the duties of President during the last three years. The motion was carried by acclammation.

10. Mr. Henry Dyer, M.A., C.E., read a paper "On Technical Education, with special reference to the requirements of Glasgow and the West of Scotland." On the motion of the President, a vote of thanks was awarded to Mr. Dyer. It was agreed to print the paper immediately, and it was left to the Council to circulate amongst Members of the Society and others interested in the question such a number of copies as they might deem advisable. The discussion of the paper was adjourned till the 5th of December.

11. The President announced that the following gentlemen had been duly elected Members of the Society:—

Mr. Arthur Hart, Woodlands Terrace; Mr. George A. Mitchell, Coal Master, 67 West Nile Street; Mr. William Grant Paton, 11 Kersland Terrace, Hillhead; Mr. James Thomson Tullis, Anchorage, Burnside, Rutherglen.

(Signed) HENRY MUIRHEAD.

5th December, 1883.

The Second Ordinary Meeting for Session 1883-4 was held on the evening of the 5th of December, 1883, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Members were admitted:—

Mr. Arthur Hart, Woodlands Terrace; Mr. George A. Mitchell, Coal Master, 67 West Nile Street; Mr. William Grant Paton, 11 Kersland Terrace, Hillhead; Mr. James Thomson Tullis, Anchorage, Burnside, Rutherglen.

3. The following were proposed for the Membership of the Society:—

Mr. William Ewing, 7 Royal Bank Place. Recommended by Dr. George A. Turner, Dr. James Christie, and Professor M'Kendrick.

Mr. James Yate Johnson, C.E. and Patent Agent. Recommended by Mr. St. John V. Day, C.E., F.R.S.E., Mr. William Renny Watson, and Mr. James Thomson.

Mr. C. Brown Ritchie, Writer, 79 West Regent Street. Recommended by Mr. John Mayer, F.C.S., Mr. James Sellars, Architect, and Dr. Abraham Wallace.

Rev. F. L. Robertson, D.D., 204 Bath Street. Recommended by Dr. W. G. Blackie, F.R.G.S., Mr. J. Alexander Blackie, and Mr. William Ker.

Mr. Thomas M. Welch, Engineer, 63 St. Vincent Crescent. Recommended by Mr. Anthony Inglis, Mr. John Inglis, and Mr. William Nowery.

Mr. John G. Hudson, 18 Aytoun Road, Pollokshields. Recommended by Mr. St. John V. Day, C.E., Sir William Thomson, and Mr. R. A. Robertson.

4. Mr. William Foulis, C.E., showed a number of beautiful experiments with Gas Flames, and more especially an Incandescent Gas-burner. He was awarded a vote of thanks.

5. A discussion took place on Mr. Henry Dyer's Paper on Technical Education, read on the 21st of November. The discussion was opened by Mr. E. M. Dixon, B.Sc., and was carried on by Professor James Thomson, Dr. W. G. Blackie, the Rev. Dr. Williamson, the Rev. Dr. F. L. Robertson, Mr. Walter Macfarlane, Mr. D. M. Nelson, Mr. Andrew Jamieson, Mr. John Honeyman, Mr. Thomas Muir, Mr. Nathaniel Dunlop, and Mr. Fife. Mr. Dyer having briefly replied, the discussion was brought to a close by a vote of thanks being awarded to Mr. Dyer.

6. The President announced that the following gentlemen had been duly elected Members of the Society:—

Mr. Francis Walter Allan, Merchant, 15 Gordon Street; Mr. John Edwards, Govanhaugh Dyeworks; Mr. George G. Henderson, B.Sc., 1 Westbourne Terrace, Kelvinside; Mr. James Goldie, 40 St. Enoch Square; Mr. A. C. Macintyre, 4 Park Terrace, Queen's

Drive; Dr. Angus Macphee, 327 St. George's Road; Mr. Robert George Munsie, 16 Royal Terrace, West; Mr. Joseph F. Newlands, Stockbroker, 28 Renfield Street; Mr. Walter Steuart, 12 Pollok Road, Pollokshaws; Mr. John S. Stewart, Measurer, 42 Bath Street; Mr. David Inglis Urquhart, Merchant, 47 Westbourne Gardens; Mr. Charles Watt, Merchant, 13 Dundas Street; Mr. Hugh Barnett, Merchant, Elmwood, Crosshill; Mr. James Barr, C.E. and Surveyor, 132 West Regent Street; Mr. Thomas Buchan, Brassfounder, 249 Argyle Street; Mr. R. M. Downie, 1 Dundas Street; Mr. David M'Houl, Ph.D., Buchanan Villa, Shawlands; Mr. William Copland Wood, Alexandria Turkey-red Works; Mr. William A. Verel, The Linn, Cathcart; Mr. Archibald H. Ewing, 41 St. Vincent Place.

(Signed) HENRY MUIRHEAD.

19th December, 1883.

The Third Ordinary Meeting for Session 1883-4 was held on the evening of the 19th of December, 1883, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Members were admitted:—

Mr. Francis Walter Allan, Merchant, 15 Gordon Street; Mr. John Edwards, Govanhaugh Dyeworks; Mr. George G. Henderson, B.Sc., 1 Westbourne Terrace, Kelvinside; Mr. James Goldie, 40 St. Enoch Square; Mr. A. C. Macintyre, 4 Park Terrace, Queen's Drive; Dr. Angus M'Phee, 327 St. George's Road; Mr. Robert George Munsie, 16 Royal Terrace, West; Mr. Joseph F. Newlands, Stockbroker, 28 Renfield Street; Mr. Walter Steuart, 12 Pollok Road, Pollokshaws; Mr. John S. Stewart, Measurer, 42 Bath Street; Mr. David Inglis Urquhart, Merchant, 47 Westbourne Gardens; Mr. Charles Watt, Merchant, 13 Dundas Street; Mr. Hugh Barnett, Merchant, Elmwood, Crosshill; Mr. James Barr, C.E. and Surveyor, 132 West Regent Street; Mr. Thomas

Buchan, Brassfounder, 249 Argyle Street; Mr. R. M. Downie, 1 Dundas Street; Mr. David M'Houl, Ph.D., Buchanan Villa, Shawlands; Mr. William Copland Wood, Alexandria Turkey-red Works; Mr. William A. Verel, The Linn, Cathcart; Mr. Archibald H. Ewing, 41 St. Vincent Place.

3. The following were proposed for the Membership of the Society:—

Mr. Robert Scott, Measurer, 163 West George Street. Recommended by Mr. James Mowatt, Mr. A. Lindsay Miller, and Mr. David Thomson.

Mr. Rankin Kennedy, Electrician, Rosehill Works, Polmadie. Recommended by Mr. Wallace Fairweather, C.E., Dr. Henry Muirhead, and Mr. John Mann.

4. Dr. William Wallace read a paper "On the Decline in the use of Coffee in this Country," for which he was awarded a vote of thanks. A discussion ensued, in which Dr. Robert Bell, Dr. Williamson, Mr. J. J. Coleman, Mr. James Thomson, F.G.S., and Mr. T. L. Patterson, Greenock, took part.

5. Principle Jamieson read a paper "On Tests of Aluminium and Copper Wire for Electric purposes," for which he received the thanks of the Society.

6. Dr. J. J. Dobbie read a paper "On an improved form of Goniometer," and exhibited the instrument.

7. Dr. Dobbie also exhibited and explained an Apparatus designed by him for "Illustrating Crystallographic Axes." The thanks of the Society were voted to Dr. Dobbie for both of his communications.

8. Notice of the following motion for next Meeting was given on behalf of Mr. J. Cleland Burns, viz.:—"That a deputation from this Society be appointed to wait upon the Lord-Advocate in Edinburgh, for the purpose of explaining to him the urgent necessity which exists for the amendment of 'The Public Health (Scotland) Act, 1867,' in accordance with the Memorial sent by this Society to his Lordship and to Lord Rosebery last Session."*

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* *Vide* Society's *Proceedings* for 1882-83, vol. xiv., p. 544.

9. The President announced that the following gentlemen had been duly elected Members of the Society:—

Mr. William Ewing, 7 Royal Bank Place; Mr. James Yate Johnson, C.E. and Patent Agent, 115 St. Vincent Street; Mr. C. Brown Ritchie, Writer, 79 West Regent Street; Rev. F. L. Robertson, D.D., 204 Bath Street; Mr. Thomas M. Welch, Engineer, 63 St. Vincent Crescent; Mr. John G. Hudson, 18 Aytoun Road, Pollokshields; Mr William Begg, Wire Cloth Manufacturer, 636 Springfield Road, Parkhead; Mr. Alexander Nicholson, Jun., Boilermaker, 6 Annfield Place, Glasgow.

(Signed) HENRY MUIRHEAD.

9th January, 1884.

The Fourth Ordinary Meeting for Session 1883-4 was held on the evening of the 9th of January, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Members were admitted:—

Mr. William Ewing, 7 Royal Bank Place; Mr. James Yate Johnson, C.E. and Patent Agent, 115 St. Vincent Street; Mr. R. Brown Ritchie, Writer, 79 West Regent Street; Rev. F. L. Robertson, D.D., 204 Bath Street; Mr. Thomas M. Welch, Engineer, 63 St. Vincent Crescent; Mr. John G. Hudson, 18 Aytoun Road, Pollokshields; Mr. William Begg, Wire Cloth Manufacturer, 636 Springfield Road, Parkhead; Mr. Alexander Nicholson, Jun., Boilermaker, 6 Annfield Place.

3. The following gentleman was proposed for the Membership of the Society:—

Mr. George Christie Young, Timber Merchant, City Saw Mills, Port-Dundas. Recommended by Mr. E. M. Dixon, Dr. James Morton, and Mr. John Mann.

4. Sir William Thomson read a paper "On the Measurement of Electric Currents and Potentials," illustrated by a variety of Instruments, the mechanism and manner of using which were explained, with suggestions for future instruments. Principal Jamieson and Professor Blyth offered a few remarks.

5. Sir William Thomson afterwards submitted a paper "On Measurements made by Mr. Abdank and himself in the Vienna Electric Exhibition on the current yielded by the new Voltaic element of Lalande." A cordial vote of thanks was passed to Sir William for his valuable communications.

6. In the absence of Mr. J. Cleland Burns, Dr. Eben. Duncan, on his behalf, gave renewed notice of the following Motion for next Meeting, viz.:—"That a deputation from this Society be appointed to wait upon the Lord Advocate in Edinburgh, for the purpose of explaining to him the urgent necessity which exists for the Amendment of 'The Public Health (Scotland) Act, 1867,' in accordance with the Memorial sent by this Society to his Lordship and to Lord Rosebery last Session."*

7. The President announced that the following gentlemen had been duly elected Members of the Society:—

Mr. Robert Scott, Measurer, 163 West George Street; Mr. Rankin Kennedy, Electrician, Rosehill Works, Polmadie.

(Signed) HENRY MUIRHEAD.

23rd January, 1884.

The Fifth Ordinary Meeting for Session 1883-84 was held on the evening of the 23rd of January, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

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* *Vide* Society's *Proceedings* for 1882-83, vol. xiv., p. 544.

2. The following new Members were admitted :—

Mr. Robert Scott, Measurer, 163 West George Street; Mr. Rankin Kennedy, Electrician, Rosehill Works, Polmadie.

3. An "Analysis of the Dust-rain which fell during the Eruption of Cracatoa, Java, 27th August, 1883," communicated by Mr. Jas. L. Mitchell, was exhibited, and remarked on by the President, Dr. Wallace, and Mr. John Mayer.

4. Mr. J. J. Coleman, F.I.C., F.C.S., read a paper "On a New Method of Measuring the Heat-conducting Power of various Materials, including Wool, Cotton, Hair, Wood-shavings, Wood-char, Breeze, &c." Professor James Thomson, Mr. H. K. Bromhead, the President, Dr. Wallace, and Mr. N. Dunlop made a few remarks on the subject, and Mr. Coleman replied.

5. Mr. Coleman read another paper "On a New Thermometer for Measuring Low Temperatures," illustrated by apparatus designed by him, including suggestions for a large-scale Thermometer for ordinary temperatures. Mr. Mayer, Professor James Thomson, Dr. Wallace, and Mr. Alexander Scott took part in a short discussion which followed.

6. Mr. Coleman read a third paper "On Mithoff's Metallic Spiral Hygroscope," which was shown in action, with other instruments. Dr. Eben. Duncan and Mr. Mayor offered a few remarks, and Mr. Coleman replied. A hearty vote of thanks was given to Mr. Coleman for these three papers, which were communications from the Chemical Section.

7. In absence of Mr. J. Cleland Burns, Dr. Eben. Duncan moved, in terms of notice—"That a deputation from this Society be appointed to wait upon the Lord-Advocate in Edinburgh, for the purpose of explaining to him the urgent necessity which exists for the Amendment of 'The Public Health (Scotland) Act, 1867,' in accordance with the Memorial sent by this Society to his Lordship and to Lord Rosebery last Session," which was seconded by Mr. W. R. W. Smith.

Mr. John Mayer moved "the previous question," which was seconded by Mr. Archibald Robertson.

A discussion followed, in which Dr. Wallace, Mr. Smith, the President, Dr. Morton, Mr. Alex. Scott, and Dr. Duncan took

part, the feeling of the opponents of the Motion being that, while the objects advocated in the Memorial were very desirable, yet, to send a Deputation would be an innovation on the practice of the Society, and might become an inconvenient precedent. Ultimately the Motion was withdrawn.

8. The following gentleman was proposed for the Membership of the Society :—

Mr. Samuel Marks, Oil Merchant, 5 Whitehill Gardens, Dennistoun. Recommended by Mr. J. J. Coleman, Mr. Alexander Scott, and Mr. Archibald Robertson.

9. The President announced that the following gentleman, balloted for, had been duly elected a Member of the Society, viz.:—

Mr. George Christie Young, Timber Merchant, City Saw Mills, Port-Dundas.

(Signed) HENRY MUIRHEAD.

6th February, 1884.

The Sixth Ordinary Meeting for Session 1883-4 was held on the evening of the 6th February, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Member was admitted :—

Mr. George Christie Young, City Saw Mills, Port-Dundas.

3. Dr. J. J. Dobbie read a paper "On the recent Progress of Chemistry at home and abroad; a plea for the teaching of higher Chemistry in this country." Dr. E. J. Mills, F.R.S., and Mr. Alexander Whitelaw expressed their high appreciation of the paper, and a hearty vote of thanks was passed to the author.

4. The following gentleman was proposed for the Membership of the Society :—

Mr. R. A. Whytlaw, Jun., 1 Windsor Quadrant, Kelvinside.

5. The President announced that the following gentleman, balloted for, had been duly elected a Member of the Society, viz.:—

Mr. Samuel Marks, Oil Merchant, 5 Whitehill Gardens, Dennistoun.

(Signed) HENRY MUIRHEAD.

20th February, 1884.

The Seventh Ordinary Meeting for Session 1883-84 was held on the 20th of February, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street, Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Member was admitted :—

Mr. Samuel Marks, 5 Whitehill Gardens, Dennistoun.

3. The following gentlemen were proposed for the Membership of the Society, viz.:—

Mr. Archibald Russell Miller, The Cairns, Cambuslang. Recommended by Mr. T. P. Miller, Dr. Henry Muirhead, and Mr. John Mann.

Mr. Charles C. Bryce, Merchant, 141 West George Street. Recommended by Mr. T. P. Miller, Dr. Henry Muirhead, and Mr John Mann.

Mr. Matthew Henderson, Wright and Builder, 4 Grant Street. Recommended by Mr. Archibald Robertson, Mr. Robert J. Bennett, and Mr. Robt. A. Bryden.

4. The President then resigned the Chair to Mr. R. R. Tatlock, F.R.S.E., F.I.C., F.C.S., as President of the Chemical

Section, under the auspices of which Section the Second Triennial "Graham Lecture" had been arranged to be delivered, subject, "The Life and Works of Thomas Graham, late Master of the Mint," prepared by Dr. R. Angus Smith, F.R.S., Manchester. In the unavoidable absence of the author, the lecture was read by Professor Ferguson, M.A., one of the permanent Vice-Presidents of the Section.

5. The following gentleman, balloted for, was duly elected a Member of the Society, viz.:—

Mr. R. A. Whytlaw, Jun., 1 Windsor Quadrant, Kelvinside.

(Signed) HENRY MUIRHEAD.

5th March, 1884.

The Eighth Ordinary Meeting for Session 1883-4 was held on the 5th of March, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Member was admitted:—

Mr. R. A. Whytlaw, Jun., 1 Windsor Quadrant, Kelvinside.

3. Dr. W. G. Blackie, F.R.G.S., as President of the Geographical and Ethnological Section, delivered an Opening Address on "Geography and Ethnology, what these embrace," for which he received a hearty vote of thanks.

4. Rev. Alexander Williamson, LL.D., author of "Journeys in North China," &c., then read a paper "On some of the chief features of the Physical Geography, including the Geology, of China, and the bearing thereof on the future of that Empire;" being a communication from the Geographical and Ethnological Section.

The Chairman moved a vote of thanks to Dr. Williamson for his very interesting paper, which was supported by Dr. Blackie and Mr. W. R. W. Smith, and heartily agreed to.

5. The President announced that the following gentlemen, balloted for, had been duly elected Members of the Society, viz.:—

Mr. Archibald Russell Miller, The Cairns, Cambuslang; Mr. Charles C. Bryce, Merchant, 141 West George Street; Mr. Matthew Henderson, Wright and Builder, 4 Grant Street.

(Signed) HENRY MUIRHEAD.

19th March, 1884.

The Ninth Ordinary Meeting for Session 1883-4 was held on the 19th of March, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. The following new Members were admitted:—

Mr. Archibald Russell Miller, The Cairns, Cambuslang; Mr. Charles C. Bryce, Merchant, 141 West George Street; Mr. Matthew Henderson, Wright and Builder, 4 Grant Street.

3. Mr. A. Crum Maclae, Writer, 149 St. Vincent Street, was proposed for the Membership of the Society by Dr. Andrew Fergus, Dr. Henry Muirhead, and Dr. M'Kendrick.

4. On the motion of the President, seconded by Mr. Thomas Muir, Professor Grant, L.L.D., F.R.S., &c., Honorary Vice-President, of the Observatory, Glasgow, was awarded the thanks of the Society for a copy of his "Glasgow Catalogue of 6,415 Stars for the Epoch 1870," presented by him to the Library, and he was congratulated on the completion of this great work.

5. Mr. William Limont, M.A., M.B., Lecturer on Physiology in the Western Medical School, made a communication "On the modern forms of the Microscope from a Physiological and Pathological point of view," for which he received the thanks of the Society. The paper was sent from the Biological Section.

6. Dr. Robert Bell read a paper "On House Sanitation," for which he received the thanks of the Society.

(Signed) HENRY MUIRHEAD.

2nd April, 1884.

The Tenth Ordinary Meeting for Session 1883-4 was held on the 2nd of April, 1884, at Eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling the Meeting, were held as read, and were approved and signed by the Chairman.

2. Dr. Henry Muirhead, President, read a "Note on Mr. Joseph Whitley's Centrifugal Mode of Casting Steel Plates for Shipbuilding, &c." He then presented to the Society a large Model, in bronze, of Cleopatra's Needle, cast by Mr. Joseph Whitley, and read an interesting account of the inscriptions theron. On the motion of Mr. Alexander Scott, a cordial vote of thanks was given to Dr. Muirhead, both for his papers and for the handsome gift to the Society.

3. Dr. James J. Dobbie gave a "Demonstration of an easy and rapid Method of determining the Specific Gravity of Solids," invented by Mr. John C. Hutcheson and himself, for which the authors received the thanks of the Society.

4. Mr. James Thomson, F.G.S., President of the Biological Section, read a paper "On the prevalence of Rickets in the City of Glasgow and in the West of Scotland, and the relation of Rickets to the Food and Water used." The paper was illustrated by a microscopical demonstration of sections of healthy and of

diseased bones. Mr. Thomson was awarded a cordial vote of thanks.

5. Mr. Alexander Scott, Vice-President, who occupied the Chair, at the close of the meeting announced that Mr. A. Crum Maclae, Writer, 149 St. Vincent Street, had been duly elected a Member of the Society.

(Signed) HENRY MUIRHEAD.

16th April, 1884.

The Eleventh Ordinary Meeting for Session 1883-4 was held on the 16th of April, 1884, at Eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Dr. Henry Muirhead, President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. Dr. W. Blackie, F.R.G.S., President of the Geographical and Ethnological Section, read a paper entitled "Sketch of the present state of our knowledge of the Island of New Guinea," for which he received the thanks of the Society.

3. The President gave notice that, at next Meeting, he would ask the Society to authorise himself and the Secretary to sign a Petition to the House of Commons in favour of Mr. Bryce's Bill as to Moors and Forests.

(Signed) ALEXANDER SCOTT.

30th April, 1884.

The Twelfth and last Ordinary Meeting for Session 1883-4 was held on the 30th of April, 1884, at eight o'clock p.m., in the Rooms of the Society, 207 Bath Street—Mr. Alexander Scott, Vice-President, in the Chair.

1. The Minutes of last Meeting of the Society, having been printed in the Notice calling this Meeting, were held as read, and were approved and signed by the Chairman.

2. Mr. Andrew Hamilton, 2 Belmar Terrace, Pollokshields, was proposed for the Membership of the Society by Mr. W. R. W. Smith, Dr. William Wallace, and Mr. John Mann.

3. Professor James Blyth, M.A., F.R.S.E., read a paper "On a new form of Galvanometer and Voltometer," for which he received the thanks of the Society. Various forms of the instrument were exhibited.

4. Mr. Alexander Pinkerton read a paper entitled "How Smoke can be profitably Consumed," for which he received the thanks of the Society.

5. Professor M'Kendrick read a "Sketch of the Life and Work of the late Professor Allen Thomson."

6. On the motion of the Chairman, the Reports of the various Sections were taken as read, and were remitted to the Council for publication in the "Proceedings."

7. On the motion of Mr. Archibald Robertson, seconded by Mr. James Thomson, F.G.S., the President and Secretary were authorised to sign, and to affix the Seal of the Society to, a Petition to the House of Commons in favour of Mr. Bryce's Bill as to access through Moors, Forests, &c.

BALANCE SHEET OF THE THOMAS GRAHAM MEDAL AND LECTURE FUND. SESSION 1882-83.

	To Subscriptions invested in 4 per cent. Preference Shares of the Glasgow & South-Western Railway Company,	£250	0	0	By Die, - - -	£18	18	0
	,, Dividends upon above Shares lodged in Union Bank as per Balance of 1881, -	4	17	9	,, Balance, - -	275	16	6
1882.	,, Dividends lodged in Union Bank, -	9	15	3	viz:—Invested, £250 0 0; Available, 25 16 6; £275 16 6			
1883. Ap. 12.	,, Dividends lodged in Union Bank, -	4	17	4				
Oct. 2.	,, Dividends lodged in Union Bank, -	4	17	9				
	,, Cash in Treasurer's hands, - -	1	8	5				
	,, Value of Die lying at H. M. Mint, -	18	18	0				
		£294	14	6		£294	14	6

J. J. COLEMAN, *Treasurer.*
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In accordance with Minute of 30th April, the following Petition was forwarded to Dr. Cameron, M.P., and was presented to the House of Commons:—

UNTO THE HONOURABLE THE COMMONS OF THE UNITED KINGDOM OF GREAT BRITAIN AND IRELAND, IN PARLIAMENT ASSEMBLED.

THE HUMBLE PETITION OF THE PHILOSOPHICAL SOCIETY OF GLASGOW,

SHEWETH,

That the Philosophical Society of Glasgow, now holding its Eighty-first Session, consists of upwards of Seven Hundred Members, many of whom are engaged in the cultivation of the various sciences.

That the Society has had under its consideration the provisions of a Bill introduced into your Honourable House, entitled "A Bill to secure to the Public Access to Mountains and Moorlands in Scotland."

That your Petitioners believe and humbly submit that the exclusion of scientific men, and especially of those engaged in the study of Natural History, from many large tracts of moorland and uncultivated districts has been prejudicial to the advancement of science; and that the grounds on which such exclusion is based do not warrant its continuance, and that it therefore should be removed.

That your petitioners are of opinion that the principles involved, and the restrictions proposed in the said Bill, would not operate prejudicially to the rights of the proprietors of the soil, whilst they would have a beneficial effect in promoting scientific research.

That for these and other reasons your Petitioners are earnestly desirous that the Measure referred to should pass into law.

Your Petitioners therefore humbly pray your Honourable House to pass the said Bill into law.

And Your Petitioners, as in duty bound, shall ever pray.

Signed, in name and on behalf of the Members of the Philosophical Society of Glasgow, by

HENRY MUIRHEAD, *President.*
JOHN G. M'KENDRICK, *Secretary*

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Annual Report of Stirling's and Glasgow Library. Pamphlet. 1882-3, ...	The Managers.
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,, Magnetical and Meteorological Observations, 1881, ...	,,
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Catalogue of Books bequeathed to Anderson's College by Alex. Laing. 1883, ...	The Trustees.
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Dutton's Tertiary History of the Grand Canon District. Vol. 2. With large folio Atlas. 1882, ...	U.S. Geological Survey.
Second Annual Report of the U.S. Geological Survey. By J. W. Powell. 1880-1, . .	,,
The Territories Wyoming and Idaho, with Maps. Two Parts. By F. V. Hayden. 1883, . .	,,
Palæontologia Indica. Series X., Vols. 2-6. 1884, ... , ...	The Geological Survey of India.
On the Discovery of the Periodic Law, and on Relations among the Atomic Weights. 1884. By J. A. R. Newlands, ...	The Author.

BOOKS BOUGHT IN ADDITION TO THE JOURNALS NAMED ON PAGES 398, 399.

Jahres-bericht der Chemischen Technologie. 1882.
Micrographic Dictionary. 4th Edition. 1883.
Sang's New Table of Seven-Place Logarithms of Numbers continuously up to 200,000.
Association Française. 11me Session. La Rochelle. 1882.
Grove's Dictionary of Music. Vol. III.
The Organs of Speech. By George Hermann von Meyen. 1883.
Encyclopædia Britannica. Vol. XVI. 1883.
La Nature. 1883.
Weltliteratur der Elektricität und des Magnetismus.
Memoirs of Sir William Hamilton, Bart. By John Veitch. 1869.
Mental Evolution in Animals. By George J. Romanes. 1883.
Travels and Researches in Japan. By J. J. Rein. 1884.
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The Statesman's Year Book. 1884.
Mineral Statistics of Great Britain and Ireland. 1884.
Life and Works of Michael Angelo Buonarroti. By C. Heath Wilson. 1876.
Lectures on Architecture. By Edward le Barry. 1881.
Samoa a Hundred Years Ago and long before. By George Turner. 1884.
Die Magnet-und Dynamo-Elektrischen Maschinen, &c. By Dr. H. Schellen. 1883.
Aesthetik Kunstgewerbes. By Jacob von Falke. No date.
Die Technologie der Fette und Oele des Pflanzen-und-Thierreichs. By Dr. Carl Schaedler. 1882.
An Index to Periodical Literature. By W. Frederick Poole. 1882.
Encyclopædia Americana. Vol. I. 1883.
New English Dictionary. Part I. Edited by Dr. James A. H. Murray. 1884.
Monograph of the Insectivora. Parts I., II. By G. E. Dobson. 1882-3.
On the Nature of Light. By George G. Stokes. 1884.
Zoological Record. Vol. XIX. 1882.
Egypt and the Egyptian Question. By D. Mackenzie Wallace. 1883.
Scotland in Pagan Times. By Joseph Anderson. 1883.
Reprint of Papers on Electrostatics and Magnetism. By Sir William Thomson.
On the Motion of Vortex Rings. 1883. By J. J. Thomson.
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Architect.
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British Architect.
British Medical Journal.
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Building News.
Chemical News.
Comptes Rendus.
Dingler's Polytechnisches Journal.
Electrician.
Engineer.
Engineering.
English Mechanic.
Iron.
Journal of the Society of Arts.
Journal of Gas Lighting.
Nature.
Notes and Queries.
Pharmaceutical Journal.
Science.
Scientific American.
Telegraphic Journal.

FORTNIGHTLY.

Berichte der Deutschen Chemischen Gesellschaft.
Bulletin de la Société Chimique de Paris.
Journal für Praktische Chemie.

MONTHLY.

American Journal of Science and Arts.
Annales de Chimie et de Physique.
Annales des Ponts et des Chaussées.
Annales des Sciences Naturelles—Botanique.
Annales des Sciences Naturelles—Zoologie.
Annalen der Chemie.
Annalen der Physik und Chemie.
Annals and Magazine of Natural History.
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Journal of the Franklin Institute.
Geological Magazine.
Hardwicke's Science Gossip.
Journal de Pharmacie et de Chimie.
Journal of Botany.
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Journal of Science.
Journal of the Chemical Society.
London, Edinburgh, and Dublin Philosophical Magazine.
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Proceedings of Royal Society of London.
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Sanitary Journal.
Science Monthly.
Zoologist.

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Quarterly Journal of Microscopical Science.
Quarterly Journal of Ornithology.
Quarterly Journal of Pure and Applied Mathematics.
Revue Universelle des Mines.
Scientific Roll.
Zeitschrift für Analytische Chemie.

LIST OF MEMBERS

OF THE

PHILOSOPHICAL SOCIETY OF GLASGOW,

FOR 1883-84.

* *Denotes Life Members.*

HONORARY MEMBERS.

(Limited to Twenty.)

WITH YEAR OF ELECTION.

FOREIGN.

	Michael Eugene Chevreul, Paris,	1860
	Hermann Ludwig Ferdinand von Helmholtz, Berlin,	1860
	Rudolph Albert Kölliker, Würtzburg,	1860
	Wilhelm Weber, Göttingen,	1860
5	Ernst Heinrich Hæckel, Jena,	1880

AMERICAN AND COLONIAL.

	James Dwight Dana, LL.D., Professor of Geology and Mineralogy in Yale College, Connecticut,	1860
	Elias Loomis, Professor of Natural Philosophy, Yale College, Connecticut,	1860
	Robert Lewis John Ellery, F.R.A.S., Victoria,	1874
	John William Dawson, LL.D., F.R.S., Principal of Macgill College, Montreal,	1883

BRITISH.

10	James Prescott Joule, LL.D., D.C.L., F.R.S., Manchester,	1860
	Sir Andrew Crombie Ramsay, LL.D., F.R.S., London,	1874
	Sir Joseph Dalton Hooker, K.C.B., K.C.S.I., M.D., D.C.L., LL.D., Kew, London,	1874
	Thomas Henry Huxley, Ph.D., LL.D., P.R.S., London,	1876
	Herbert Spencer, London,	1879
15	John Tyndall, LL.D., D.C.L., F.R.S., M.R.I., London,	1880

CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

Rev. H. W. Crosskey, LL.D., F.G.S., 117 Gough road, Birmingham, . . . 1874
Robert Gray, F.R.S.E., Bank of Scotland, Edinburgh, ... 1874
A. S. Herschel, B.A., F.R.S., F.R.A.S., Professor of Physics, College of Science, 16 Saville row, Newcastle-on-Tyne, ... 1874
Thomas E. Thorpe, Ph.D., F.R.S., Professor of Chemistry in College of Science, Leeds, ... 1874
5 John Aitken, F.R.S.E., Darroch, Falkirk, ... 1883
Alex. Buchan, M.A., F.R.S.E., Secretary to the Scottish Meteorological Society, 73 Northumberland Street, Edinburgh, ... 1883
James Dewar, M.A., F.R.S., L. & E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 19 Brookside, Cambridge, ... 1883
Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeons' Hall, Edinburgh, ... 1883
Joseph Swan, Newcastle-on-Tyne and London, ... 1883
10 E. A. Wünsch, London, ... 1883

ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

Adam, William, M.A., 34 Garturk street, Govanhill. 1876
Addie, John, 144 St. Vincent street. 1861
Alexander, Jas. W., 49 West Regent street. 1876
Alexander, Thos., 8 Sardinia terrace. 1869
5 Allen, Francis Walter, 15 Gordon st. 1883
Anderson, Alexander, 157 Trongate. 1869
Anderson, David H., Atlantic Mills, Bridgeton. 1875
Anderson, Geo., M.P., Western Club. 1856
Anderson, J. T., 41 Westbourne gardens. 1881
10 *Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace, 1873
Anderson, W. F. G., 47 Union street. 1878
Arnot, James Craig, 162 St. Vincent st. 1869
Arrol, Archibald, 16 Dixon street. 1869
Arrol, Walter, 16 Dixon street. 1869
15 Arrol, William A., 16 Dixon street. 1869
Arthur, Wm. Rae, 1 Crown gardens, Dowanhill. 1850

Bain, Sir James, F.R.S.E., 3 Park ter. 1866
Bain, Robert, 22 Dundas street. 1869
Baird, Alex. Smith, 26 Sardinia terrace, Hillhead. 1870
20 Baldie, Robert, I.A., 83 Bath street. 1870
Ball, Henry W., Cranstonhill Engine Works. 1875
Balloch, Robert, 131 St. Vincent st. 1843
Balmain, Thos., 1 Kew terrace, Kelvinside. 1881
Barclay, Charles H., 28 Westbourne gardens. 1881
25 Barclay, James, 36 Windsor terrace. 1872
Barclay, John, 37 Monteith row. 1881
Barlow, John, M.D., Lecturer on Physiology in Royal Infirmary School, 35 Kelvingrove street. 1880
Barnet, Hugh, Elmwood, Crosshill. 1883
Baronsfeather, W. N., 7 Berlin terrace, Pollokshields. 1883
30 Barrett, Francis Thornton, Mitchell Library. 1880
*Barr, James, 132 West Regent st. 1883
Barr, Thos., M.D., F.F.P. & S.G., 7 Albany place. 1879
Bayne, A. Malloch, 1 Hamilton terrace, Partick, 1878
Beatson, George T., B.A. Cantab., M.D., 2 Royal crescent. 1881
35 Begg, Wm., 636 Springfield road. 1883
*Beith, Gilbert, 1 Dundas street. 1881
Bell, Dugald, 27 Lansdowne cres. 1871
Bell, George, F.R.I.B.A., 212 St. Vincent street. 1870
*Bell, Henry, 5 Cornwall terrace, Regent's Park, London, N.W. 1876
40 Bell, James, 172 Argyle street. 1877
Bell, Robt., M.D., F.F.P.S.G. and Ed., 29 Lynedoch street. 1869
Bennett, Alfred R., 8a Royal Exchange buildings. 1882
Bennett, Robert J., 8 Holland place. 1883
Binnie, J., 69 Bath street. 1877
45 Binnie, Robert, Ashbourne, Gourock. 1881
Black, Adam Elliot, C.A., F.C.S., 13 South Park terrace, Hillhead. 1880
Black, D. A., 214 Bath street. 1880
Black, D. Campbell, M.D., M.R.C.S.E., 50 Woodlands road. 1872

Black, J. Albert, 33 Lynedoch st. 1869
50 Black, John, 16 Park terrace. 1869
Black, Malcolm, M.B., C.M., 5 Canning place. 1880
*Blackie, J. Alexander, 17 Stanhope street. 1881
*Blackie, J. Robertson, 17 Stanhope street. 1881
Blackie, Robert, 17 Stanhope st. 1847
55 Blackie, W. G., Ph.D., F.R.G.S., 17 Stanhope street. 1841
Blair, G. M'Lellan, 2 Lilybank ter. 1869
Blair, J. M'Lellan, 8 Cecil place, Paisley road. 1869
Blyth, James, M.A., F.R.S.E., Professor of Mathematics and Natural Philosophy in Anderson's College. 1881
Bost, Timothy, 33 Renfield street. 1876
60 Bottomley, James T., M.A., F.R.S.E., F.C.S., Demonstrator in Natural Philosophy, University of Glasgow, 13 University gardens, Hillhead. 1880
Bottomley, Wm., Junr., C.E., University. 1880
Boucher, J., I.A., 247 St. Vincent st. 1870
Bowie, Campbell T., 26 Bothwell street. 1870
Boyd, John, Shettleston Iron Works, near Glasgow. 1873
65 Boyd, Wm., Blythswood Foundry, 61 North street. 1852
Brand, James, C.E., 172 Buchanan st. 1880
Brodie, John Ewan, M.D., C.M., F.F.P.S.G., 1 Albany place. 1873
Bromhead, Horatio K., I.A., A.R.I.B.A., 245 St. Vincent st. 1870
Brown, James, 76 St. Vincent st. 1876
70 Brown, John, 22 Renfield street. 1879
Brown, John C., 149 W. George st. 1880
*Brown, John, 11 Somerset place. 1881
Brown, Nicol, 34 Canonbury park, London, N. 1869
Brown, Richard, Strone Colliery Co., 49 W. George street. 1855
75 Brown, Robert, 19 Jamaica street. 1882
Brownlee, J., 23 Burnbank gardens. 1860
Brownlie, Archibald, Bank of Scotland, Barrhead. 1880
Brownlie, Jas., Victoria Saw Mills. 1877
Brownlie, John, 2 Oakley terrace. 1874
80 Bruce, John Inglis, Helen st., Govan. 1869
Bruce, John L., I.A., 103 West Regent st. 1873
*Bryce, Charles C., 141 West George street. 1884
Bryce, David, 129 Buchanan street. 1872
Bryden, Robt. A., F.R.I.B.A., 15 Dalhousie street. 1870
85 Buchan, Thos., 249 Argyle street. 1883
Buchan, Wm. P., S.E., 21 Renfrew street. 1875

Buchanan, Alex. M., M.A., M.D., Professor of Anatomy in Anderson's College, 98 St. George's rd. 1876
Buchanan, G. Millar, 121 Kennedy street. 1881
Buchanan, George, A.M., M.D., Professor of Clinical Surgery in the University of Glasgow, 193 Bath street. 1875
90 Buchanan, Geo. S., 43 Lansdowne crescent 1845
Buchanan, William L., 212 St. Vincent street. 1873
Buchanan, William, 10 Carrington street, West. 1881
Burnet, John, I.A., 167 St. Vincent street. 1850
Burnet, Lindsay, Assoc. M.I.C.E., St. Kilda, Dowanhill. 1882
95 Burns, J., M.D., 15 Fitzroy place, Sauchiehall street. 1864
Burns, J. Cleland, Ferntower, Crieff. 1874

Cameron, Charles, M.D., LL.D., M.P., 104 Union street. 1870
Cameron, H. C., M.D., 203 Bath street. 1873
Cameron, R., 123 St. Vincent st. 1873
100 Campbell, J. A., LL.D., M.P., 137 Ingram street. 1848
Campbell, John D., Merroughsdale cottage, Copeland road, Govan. 1858
Campbell, J. M., Kelvingrove Museum. 1883
*Campbell, Louis, 3 Eton terrace, Hillhead. 1881
Carlile, Thomas, 27 St. Vincent pl. 1851
105 Carlton, Charles, 141 St. Vincent street. 1870
Carmichael, Neil, M.D., C.M., 29 S. Cumberland street. 1873
Carmichael, Thomas, Mount Hope, Bridge of Allan. 1879
Carrick, John, I.A., City Architect, 74 Hutcheson street. 1846
Cassels, Robert, 168 St. Vincent st. 1858
110 Cherrie, James M., Clutha cottage, Tollcross. 1876
Christie, James, A.M., M.D., F.F.P.S.G., 2 Great Kelvin terrace, Bank street, Hillhead. 1876
Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
Chrystal, W. J., Shawfield Works, Rutherglen. 1880
Church, James, 88 Renfield street. 1867
115 Church, Wm., Jun., 45 West Nile street. 1855
Church, W. R. M., C.A., 45 West Nile street. 1882
Clapperton, John, 5 Sandyford pl. 1874
*Clark, G. W., Dumbreck house. 1877

Clark, Henry E., L.R.C.S. Eng., 24 India street. 1876
120 Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
Clark, John, 9 Wilton crescent. 1872
*Clark, William, Mile-end. 1876
Clavering, Thos., 30 Gordon street. 1856
Cleland, A. B. Dick, Kilrock, Bridge of Allan. 1871
125 Clinkskill, James, 1 Holland place. 1868
Clouston, Peter, 1 Park terrace. 1861
Coats, Joseph, M.D., 31 Lynedoch st. 1873
*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
Coghill, Wm. C., 263 Argyle street. 1873
130 Coleman, J. J., F.C.S., 45 West Nile street. 1869
Collins, Sir Wm., 3 Park ter., East. 1869
Collins, Wm., Jun., Huntly gardens. 1879
Colquhoun, Jas., 158 St. Vincent street. 1876
Combe, William, 257 W. Campbell street. 1877
135 Connal, Michael, Virginia buildings. 1848
Connell, James, 182 Crookston st. 1870
Connell, Wm., 38 St. Enoch square. 1870
Copeland, Jas., 5 Rowallan quadrant, Kelvinside. 1869
Copland, Wm. R., M. Inst. C.E., 146 West Regent street. 1876
140 Coubrough, A. Sykes, Blanefield, Strathblane. 1869
Couper, James, Craigforth House, Stirling. 1862
Couper, James, 37 Lansdowne cres. 1878
Couper, Wm., 9 Huntly gardens, Hillhead. 1873
Cowan, John, 55 Forth st., Pollokshields. 1870
145 Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
Cranston, George, Jun., 425 Sauchiehall street. 1880
Crawford, David, Jun., Glengowan Print Works, Caldercruix, by Airdrie. 1873
Crawford, W. B., 104 West Regent street. 1872
Cree, Thomas S., 17 Exchange sq. 1869
150 Cross, David, 25 Park circus. 1850
Cunningham, John M., Clydesdale Bank. 1881
Cunningham, J. R., Jun., 4 Derby crescent, Kelvinside. 1881
Curphey, Wm. Salvador, 5 Broomhill drive, Partick. 1883
*Cuthbertson, John N., 29 Bath st. 1850

155 Dansken, A. B., 179 West George street. 1877
*Dansken, John, 121 West Regent street. 1876
Darling, Geo. E., 178 St. Vincent street. 1870
Davidson, T., Jun., 33 Garngadhill. 1872
Day, St. John Vincent, C.E., F.R.S.E., 115 St. Vincent street. 1866
160 Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
Dempster, John, Cambridge terrace, Albert Road, Pollokshields. 1875
Dennison, Wm., C.E., 175 Hope st. 1876
Dewar, Duncan, St. Fillans, West Coates, Cambuslang. 1877
Dickie, James, Broomfield, Stanmore, Middlesex. 1879
165 Dickson, James, 15 Binnie place. 1871
Dittmar, W., F.R.S., L. & E., Professor of Chemistry, Anderson's College. 1875
Dixon, A. Dow, 10 Montgomerie crescent, Kelvinside. 1873
Dixon, Edward M., B.Sc., 11 Hopetoun place. 1860
Dobbie, James Johnston, M.A., D.Sc., Assistant to the Professor of Chemistry, University, 292 St. Vincent street. 1880
170 Donald, John, Dennistoun Public School. 1872
Donald, William J. A., 27 St. Vincent place. 1877
Donald, Alex. W., Bank place, Cambuslang. 1880
Dougall, Franc Gibb, 167 Canning st. 1875
Dougall, John, M.D., F.F.P.S., Lecturer on Materia Medica in the Glasgow Royal Infirmary School of Medicine, 6 Belmar terrace, Shields road, Pollokshields. 1876
175 Douglas, Campbell, I.A., 266 St. Vincent street. 1870
Downie, James, North Bank house, Kirkintilloch. 1872
Downie, R. M., 1 Dundas street. 1883
Downie, Robert, Jun., Carntyne Dye-works, Parkhead. 1872
Drew, Alex., 149 West George st. 1869
180 Dryburgh, Jas. N., Minerva cottage, Holmhead, Cathcart. 1872
Duff, M. Campbell, 145 St. Vincent street. 1880
Duncan, Alex., B.A., 242 St. Vincent street. 1878
Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873
Duncan, Robert, Engineer, Partick Foundry. 1875
185 *Duncan, Walter, 9 Montgomerie crescent. 1881
Dunlop, E. D., 68 St. Vincent st. 1883
*Dunlop, Nathaniel, 1 Montgomerie crescent, Great Western road. 1870

Dunn, Robert Hunter, 4 Belmont crescent. 1878
Dyer, Henry, M.A., C.E., Dunrowan, Lenzie. 1883

190 Easton, Walter, 125 Buchanan st. 1878
Easton, William J., 150 West Regent street. 1876
Edward, David, 92 Buchanan st. 1878
Edwards, John, Govanhaugh Dye Works. 1883
Elder, James, C.E., 204 St. Vincent street. 1881
195 Ewing, Archibald, 41 St. Vincent place. 1883
*Ewing, Wm., 7 Royal Bank place. 1883

Fairlie, Colin B., C.E., 67 Renfield street. 1874
Fairweather, Wallace, C.E., 96 Buchanan street. 1880
Falconer, Patrick, 33 Hayburn crescent, Partick. 1876
200 Falconer, Thos., 50 Kelvingrove st. 1880
Farquhar, John, 13 Belhaven terrace. 1872
Fawsitt, Charles A., 4 Maule terrace, Partick. 1879
Fergus, Andrew, M.D., M.R.C.S. Eng., 191 Bath street, *Hon. Vice-President.* 1868
Fergus, Jas., 5 Burnbank gardens. 1880
205 Ferguson, John, M.A., Professor of Chemistry, University of Glasgow. 1869
Ferguson, Peter, 4 Linwood ter., Glasgow st., Hillhead. 1866
Ferguson, Thomas, Westmuir st., Parkhead. 1883
Ferguson, William Muir, 116 St. Vincent street 1883
Fergusson, Alex. A., 48 M'Alpine street. 1847
210 Fife, William, 52 Glassford street. 1880
Finlay, Joseph, 9 Montgomerie drive, Kelvinside. 1873
Finlay, Robert Gilchrist, Jun., Holmfield, Dalmuir. 1881
Finlayson, James, M.D., 351 Bath street. 1873
*Fleming, James, 136 Glebe street. 1880
215*Fleming, William James, M.D., 155 Bath street. 1876
Forbes, Alex., Undercliffe cottage, Wemyss Bay. 1879
Foulds, John, L.D.S., 173 Bath st. 1877
Foulis, William, C.E., 42 Virginia street. 1870
*Fowler, John, Kelvinbank terrace, Sandyford. 1880
220 Frame, Thomas, Royal Bank place. 1863
Frazer, Daniel, 127 Buchanan st. 1853
Frew, Alex., C.E., 175 Hope street. 1876
Frew, Robert, M.E., 75 Bath street. 1874

Gairdner, W. T., M.D., LL.D., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863
225 Galbraith, Andrew, 1 North Court, Royal Exchange. 1857
Galbraith, William, 3 Blythswood square. 1868
Gale, Jas. M., C.E., Water Office, 23 Miller street. 1856
Galloway, T. Lindsay, C.E., 27 Mair Street, Plantation. 1881
Gardner, Daniel, 36 Jamaica street. 1869
230*Garroway, John, 58 Buchanan st. 1875
Garroway, Robt., M.D., Rosemount, Cumbernauld road. 1859
Geddes, Wm., Battlefield, Langside. 1846
Gibb, Peter, 10 Granby terrace. 1883
Gillespie, Edward, Chapel Croft, Cambuslang. 1882
235 Gillies, Wm., Battlefield, Langside. 1869
Gillies, W. D., 2 Royal Exchange court. 1872
Gilfillan, Wm., 129 St. Vincent st. 1881
Glaister, John, M.B., 5 Grafton place. 1879
Goldie, James, 40 St. Enoch square. 1883
240 Goodwin, Robert, 58 Renfield st. 1875
Gorman, William, 153 West Nile st. 1860
Gossman, Adam, 79 Robertson st. 1870
Gourlay, John, C.A., 24 George square. 1874
Gourlay, Robert, Kirklee avenue, Great Western road. 1869
245 Gow, Alexander, 117 Ladbroke Grove Road, Notting hill, London, W. 1869
Gow, Robert, Cairndowan, Dowanhill gardens. 1860
Graham, David, Jun., 140 Douglas street. 1876
Grant, Robt., M.A., LL.D., F.R.S., Professor of Astronomy in the University of Glasgow, Observatory, *Hon. Vice-President.* 1860
Grant, Charles, 160 Hope street. 1883
250 Gray, James, M.D., 15 Newton terrace. 1863
Gray, James, 7 Knowe ter., Pollokshields. 1876
Greenlees, Alex., M.D., 33 Elmbank street. 1864
Grierson, James, 5 Belhaven cres., Kelvinside. 1880
Grieve, John, M.D., care of W. L. Buchanan, 212 St. Vincent st. 1856

255 Hamilton, Geo., 149 St. Vincent st. 1871
Hamilton, J. Struthers, 8 Regent Park terrace, Queen's Park. 1869
Hamilton, Patrick, 149 St. Vincent street. 1854

Hamilton, David C., 21 Carlton place. 1880
Hannay, Anthony, 23 Exchange square. 1856
260 Hannay, Jas. B., F.R.S.E., F.C.S., Annfield Chemical Works, Sword street. 1879
Hannay, Thos., 166 Buchanan st. 1864
Hannay, Maxwell, 104 West George street. 1881
Hart, Arthur, 20 Woodlands road, 1883
*Harvie, John, Secretary, Clydesdale Bank, 30 St. Vincent place. 1880
265 Hay, John, 12 Terrace street. 1870
Henderson, George G., B.Sc., 1 Westbourne terrace. 1883
*Henderson, John, Jun., 4 Crown terrace, Dowanhill. 1879
Henderson, Matthew, 4 Grant st. 1884
Henderson, Thos., 47 Union street. 1855
270 Henderson, Thos. Brown, M.D., 17 Elmbank crescent. 1880
Henderson, Wm., Winton drive, Kelvinside. 1853
*Henderson, Wm., 15 Cadogan st. 1873
*Henderson, A. P., 10 Crown terrace, Dowanhill. 1880
Henry, R. W., 8 Belhaven cres. 1875
275 Heys, Zechariah J., South Arthurlie, Barrhead. 1870
Higginbotham, James S., Springfield court, Queen street. 1874
Higgins, Henry, Jun., 252 West George street. 1878
Hill, Andrew, 22 Arlington street. 1877
Hodge, William, 11 Hillsborough square, Hillhead. 1878
280 Hoey, David G., 197 St. Vincent st. 1869
Hogg, Robert, Inglisby villa, Pollokshields. 1865
Holt, T. G., 25 Wellington street. 1875
Honeyman, John, F.R.I.B.A., 140 Bath street. 1870
Horne, R. R., C.E., 150 Hope st. 1876
285 Howatt, James, 146 Buchanan st. 1870
Howatt, William, 146 Buchanan street. 1870
Hudson, John G., 18 Aytoun road, Pollokshields. 1883
Hunt, Edmund, 87 St. Vincent street. 1856
*Hunt, John, Milton of Campsie. 1881
290 Hunter, James, Newmains house, Motherwell. 1854
Hunter, James, 156 St. Vincent st. 1874
Hutton, W. R., 4 Bath street. 1868

Inglis, John, 64 Warroch street. 1850

*Jack, William, M.A., LL.D., Professor of Mathematics in the University of Glasgow. 1881
295 Jamieson, Andrew, F.R.S.E., A.M.I.C.E., M.S.T.E., &c., Principal, College of Science and Arts. 1881
Johnson, James Yate, C.E., 115 St. Vincent street. 1883
Johnstone, Jas., Coatbridge street, Port-Dundas. 1866

Kennedy, Hugh, Redclyffe, Partick. 1876
Kennedy, Rankin, Rosehill Works, Polmadie. 1884
300 Kennedy, William, St. Margaret's, Newark Drive, Pollokshields. 1882
*Ker, William, 1 Windsor terrace, West. 1874
Kerr, Charles James, Greenfaulds house, Cumbernauld. 1877
Kerr, James Hy., 13 Virginia st. 1872
Kerr, John G., M.A., Garshake, Cambuslang. 1878
305 Key, William, Tradeston Gas-works. 1877
King, James, 57 Hamilton drive, Hillhead. 1848
King, James, of Levernholm, 115 Wellington street. 1855
Kirk, Alexander C., 19 Athole gardens, Dowanhill. 1869
Kirk, Robert, M.D., Newton cottage, Partick. 1877
310 Kirkpatrick, Andrew J., 179 West George street. 1869
Kirkwood, Anderson, LL.D., 7 Melville terrace, Stirling. 1869
Kirsop, John, 98 Argyle street. 1855
Knox, Adam, 47 Crownpoint road. 1881
Knox, John, 129 West George st. 1870
315 Knox, John, 151 Renfrew street. 1883

Laird, Geo., 10 Ann st., Bridgeton. 1870
Laird, George H., 137 Greenhead street. 1882
Laird, John, Marchmont, Port-Glasgow. 1876
Laird, John, Royal Exchange Sale Rooms. 1879
320 Lamb, Thomas, 220 Parliamentary road. 1870
Lang, William, Jun., Crosspark, Partick. 1865
Latta, James, 8 Miller street. 1869
Latta, John, 138 W. George street. 1880
Lindsay, Archd. M., M.A., 87 West Regent street. 1872
325 Lindsay, Wm. G., 157 St. Vincent street. 1871
Livingston, Robert, 263B Argyle street. 1879
*Long, John Jex, 8 Whitevale. 1862
Lothian, J. Alexander, M.D., L.R.C.S.E., 6 Newton terrace. 1872
Low, James, 176 St. Vincent st. 1878

330 M'Alley, Robert, Chemical Works, Falkirk. 1872
M'Andrew, John, 17 Park street, East. 1843
Macarthur, J. G., 7 West Prince's street. 1874
M'Call, J., F.R.C.V.S., Prof. of Veterinary Medicine and Surgery, Veterinary College, 85 Buccleuch street. 1866
Maccall, Samuel, 16 Hillsborough square, Hillhead. 1882
335 M'Callum, George, Rossbank, Cambuslang. 1850
M'Conville, John, M.D., 27 Newton place. 1870
M'Crae, John, Baronald house, Crossloan, Kelvinside. 1876
M'Creath, James, M.E., 95 Bath street. 1874
M'Culloch, William, 50 Westbourne gardens, West. 1872
340 M'Culloch, Hugh, 231 St. George's road. 1880
Macdonald, Arch. G., 8 Park circus. 1869
Macdonald, Thomas, 109 Bath st. 1869
M'Ewan, Wm., Jun., 17 St. Vincent lane. 1869
M'Farlane, Graham Jas., Elderslie. 1882
345 Macfarlane, Samuel, Meadowbank, Torrance of Campsie. 1876
Macfarlane, Walter, Saracen Foundry, Possil Park. 1855
M'Farlane, Walter, Printworks, Thornliebank. 1869
M'Gill, J. S., 8 Montgomerie Quadrant. 1869
M'Gillivray, James P., 112 Bath street. 1883
350 M'Gilvray, R. A., 129 West Regent street. 1880
M'Gregor, Duncan, F.R.G.S., 45 Clyde place. 1867
M'Gregor, Jas. W., 4 Gt. Western terrace, Hillhead. 1869
M'Gregor, James, 1 East India avenue, London, E.C. 1872
M'Grigor, Alexander B., LL.D., 172 St. Vincent street. 1857
355 M'Houl, David, Ph.D., Buchanan villa, Shawlands. 1883
*M'Ilwraith, James, 4 Westbourne terrace, Kelvinside. 1872
M'Intyre, Peter, 132 Ingram street. 1873
Macintyre, A. C., 4 Park terrace, Queen's drive. 1883
Mackay, John, Jun., 354 Sauchiehall street. 1869
360 *M'Kenzie, W. D., 43 Howard street. 1875
*M'Kenzie, W. J., 7 Great Kelvin terrace, Hillhead. 1879
*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R.C.P.E., Professor of Institutes of Medicine in the University of Glasgow, 33 Westbourne gardens, *Secretary*. 1877
Mackinlay, David, 6 Great Western terrace, Hillhead. 1855
M'Kissack, John, 234 W. George street. 1881
365 Maclae, A. Crum, 149 St. Vincent street. 1884
M'Laren, Robert, Canal street, Port-Eglinton. 1848
M'Laren, William Ed., 13 Exchange place. 1873
*Maclay, David T., 169 W. George street. 1879
Maclean, A. H., 124 Queen street. 1870
370 MacLehose, James, 18 Victoria cres., Dowanhill. 1867
MacLehose, James J., M.A., 61 St. Vincent street. 1882
M'Lellan, John Young, Blackhill house, Cumbernauld road. 1882
M'Lellan, Lewis, 7 Belhaven ter. 1869
M'Lellan, Walter, 129 Trongate. 1856
375 M'Leod, Kenneth M., 1 Montrose street. 1870
Macmillan, Daniel, F.E.I.S., 26 Ashton terrace. 1882
M'Nab, John, 69 St. Vincent street. 1881
M'Naughton, Duncan, 91 Hamilton drive, Hillhead. 1883
M'Nicol, Peter, M.A., 14 Derby terrace. 1873
380 M'Onie, Andrew, Scotland street, Tradeston. 1860
Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
Macphee, Angus, M.B., C.M., 327 St. George's road. 1883
M'Pherson, George L., 26 Albert road, Crosshill. 1872
Mactear, James, F.C.S., St. Rollox Chemical Works, *Vice-President*. 1867
385 M'Vail, D. C., M.B., 3 St. James' terrace, Hillhead. 1873
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390 Manwell, James, 4 Albert drive, Pollokshields. 1876
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*Mason, Stephen, 24 Belhaven ter. 1870
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395 Mathieson, Thomas A., 13 East Campbell street. 1869
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Mechan, Henry, 36 Elliot street. 1879
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400 Michaelson, M., 5 Woodside place. 1878
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405*Miller, Arch. Russell, The Cairns, Cambuslang. 1884
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*Miller, George, 1 Westbourne gar. 1881
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410 Miller, John (Messrs. James Black & Co.), 23 Royal Exchange sq. 1874
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415 Milligan, W. J., Laurel bank, Partick. 1881
Mills, Edmund J., D.Sc., F.R.S., Anderson's College. 1875
Milne, William, M.A., B.Sc., High School. 1881
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Mitchell, George A. 97 West Nile st. 1883
420 Mitchell, Jas. L., 10 Gt. Western terrace. 1878
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*Moffatt, Alexander, 47 Union st. 1874
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425 Moore, Robert H., 141 Onslow drive. 1876
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440 Muir, John, 6 Park gardens. 1876
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Muir, Wm., 11 Knowe terrace, Pollokshields. 1882
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*Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873
445*Muirhead, Henry, M.D., Bushy Hill, Cambuslang, *President*. 1869
*Muirhead, Robt. Franklin, B.Sc., 189 Renfrew street. 1879
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*Napier, John, 23 Portman square, London. 1849
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460 Neilson, Walter M., Queenshill, Ringford, Kirkcudbrightshire. 1843
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465 Nicol, David, Roxburgh villa, Bothwell. 1872
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470 Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870
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485 Pirie, John, M.D., 26 Elmbank crescent. 1877
*Pirrie, Robert, 9 Buckingham ter. 1875
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*Pollock, R., M.B., C.M., F.F.P.& S.G., Laurieston house, Shields road. 1883
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500 Reid, J. G., 128 St. Vincent street. 1874
Reid, Thos., M.D., 11 Elmbank street. 1869
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*Reid, William L., M.D., 7 Royal crescent, West. 1882
505 Reith, Rev. George, M.A., Free College Church, 38 Lynedoch st. 1876
Remmers, B. H., 189 St. Vincent st. 1880
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515 Robertson, John, 10 Valeview ter., Langside, *Librarian.* 1860
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535 Russell, Thomas, Cleveden, Kelvinside gardens. 1870

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*Scott, D. M'Laren, Carberry villa, Tollcross. 1881
545 Scott, Robt. 163 West George st. 1884
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555 Sinclair, D., National Telephone Co., Limited, 8a Royal Exchange buildings. 1883
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560 Smillie, R. D., M.S.T.E. and E., Messrs. Wm. Denny & Brothers, Dumbarton. 1883
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565 Smith, Hugh C., 54 Gordon street. 1861
Smith, James, 20 Park terrace. 1881
Smith, James, Benvue, Dowanhill. 1869
*Smith, J. Guthrie, 54 West Nile street. 1875
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570 Snodgrass, James, F.C.S., Walkinshaw Oil Works, near Paisley. 1878
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575 Stanford, Edward C. C., F.C.S., Glenwood, Dalmuir, Dumbartonshire. 1864
Stark, James F., Hebburn-on-Tyne. 1880
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*Stephen, John, Domira, Partick. 1880
Stephen, Robt. R., Adelphi Biscuit Factory. 1867
580 *Steven, Hugh, Westmount, Montgomerie drive. 1869
Steven, John, 32 Elliot street. 1875
Stevens, James C., 10 S. Portland street. 1882
*Stevenson, Jas., 27 St. Vincent place. 1870
Stevenson, William, Tower Bank, Lenzie. 1870
585 Stewart, David, 3 Clifton place. 1856
Stewart, Henry, City Saw Mills. 1876
Stewart, James Reid, 30 Oswald street. 1845
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Stewart, Wm., 175 St. Vincent st. 1869
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Stuart, J. Watson, 88 St. Vincent street. 1881
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595 Stoddart, James Edward, Clyde Lead Works, Cornwall street. 1872
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Strain, John, C.E., 154 West George street. 1876
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600 *Sutherland, David, 11 Clarinda ter., Pollokshields. 1880
*Sutherland, John, 11 Clarinda ter., Pollokshields. 1880
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Tatlock, Robt. R., F.R.S.E., F.I.C., F.C.S., 138 Bath street. 1868

605 Taylor, Benjamin, 10 Derby cres., Kelvinside. 1872
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Templeton, James, 2 Claremont terrace. 1876
Tennant, Charles, M.P., St. Rollox Chemical Works. 1868
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610 Terrace, David, Dawsholm Gas-works, Maryhill. 1883
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Thomson, George P., 31 Huntly gardens. 1874
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Thomson, James, I.A., F.R.I.B.A., 157 St. Vincent street. 1870
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620 Thomson, James R., Clydebank, Dumbartonshire. 1863
Thomson, John, Alliance Foundry. 1876
Thomson, Jonathan, 136 W. George street. 1869
Thomson, Wm., 75 Stockwell st. 1883
Thomson, Sir William, LL.D., D.C.L., F.R.S., L. & E., Professor of Natural Philosophy, University of Glasgow, *Hon. Vice-President.* 1846
625 Townsend, Joseph, 13 Crawford st., Port-Dundas. 1856
*Tullis, James Thomson, Anchorage, Burnside, Rutherglen. 1883
Turnbull, John, 37 West George st. 1843
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Turner, George A., M.D., 1 Clifton place, Sauchiehall street. 1883
630 Turner, William, 33 Renfield st. 1875

Ure, John, Crown Mills, 68 Washington street. 1856
Urie, John, 83 Jamaica street. 1876
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635 Waddell, Matthew, 45 Ropework lane. 1880

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640 Wallace, Abraham, M.D., 4 Newton place. 1877
*Wallace, Hugh, Mansefield, Kilmalcolm. 1879
Wallace, Wm., Ph.D., F.R.S.E., F.I.C., F.C.S., 138 Bath street, *Hon. Vice-President.* 1851
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Watson, Eben., A.M., M.D., 1 Woodside terrace. 1873
645 Watson, James, Cluniter, Innellan. 1873
Watson, Joseph, 225 West George street. 1882
*Watson, Thomas Lennox, I.A., 108 W. Regent street. 1876
*Watson, William Renny, 16 Woodlands terrace. 1870
Watt, Charles, 13 Dundas street. 1883
650 Weir, John W., M.D., F.R.C.S., Edin., 25 Sandyford place. 1875
Wells, Andw., 8 Newton terrace. 1878
Welsh, Thos. M., 51 St. Vincent crescent. 1883
Wenley, James A., Bank of Scotland, Edinburgh. 1870
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655 White, Adam, Sudbrooke, Pollokshields. 1881
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White, John, Scotstoun and Slitmills, Partick. 1875
Whitelaw, Alex., 87 Sydney st. 1855
*Whitson, Jas., M.D., F.F.P.& S.G., 13 Somerset place. 1882
660 Whytlaw, R. A., Jun., 1 Windsor quadrant, Kelvinside. 1884
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Wilson, Alex., Hydepark Foundry, 54 Finnieston street. 1874
Wilson, Alex. S., M.A., B.Sc., Professor of Botany, Anderson's College. 1880
Wilson, Charles, 4 Craigpark, Dennistoun. 1875
665 Wilson, Daniel, 124 Bothwell st. 1872
Wilson, David, Carbeth, by Killearn. 1850
Wilson, James, 144 West Regent st. 1881
Wilson, John, 11 Woodside place. 1873
Wilson, J. Veitch, The Beeches, Barlowmoor road, Didsbury, Manchester. 1874
670 Wilson, Peter M'Gregor, 40 West Nile street. 1877

Wilson, William, Virginia buildings. 1881
Wilson, W. H., 12 Waterloo st. 1881
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*Wingate, John B., 7 Crown terrace, Dowanhill. 1881
675 Wingate, P., 14 Westbourne ter. 1872
Wingate, Walter E., 4 Bowmont terrace. 1880
Wood, J. Muir, 42 Buchanan st. 1850
Wood, Wm. Copland, Turkey-red Works, Alexandria. 1883
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680 Woodburn, W. S., L.D.S., Lecturer on Mechanical Dentistry, Anderson's College, 17 Carlton place. 1881
Wyper, James, 7 Bowmont gardens. 1878

Yellowlees, D., M.D., Medical Superintendent, Gartnavel. 1881
Young, George Christie, City Saw Mills, Port-Dundas. 1884
Young, James, Jun., Kelly, Wemyss Bay. 1880
685 Young, John, 234 Parliamentary road. 1881
Young, John D., Manager Scottish Boiler Insurance Company, 162 Buchanan street. 1883
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*Young, Thos. Graham, Kelly, Wemyss Bay. 1880
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690 Zinkeisen, Victor, 30 Cochrane st. 1881

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